DENISON UNIVERSITY BULLETIN

Volume XXXVII, No. 15

JOURNAL

OF THE

SCIENTIFIC LABORATORIES

Volume XXXII Articles 3-7 Pages 133 to 207

EDITED BY

W. C. EBAUGH

Permanent Secretary Denison Scientific Association

3. Science and the College (Commemoration Address). By Carey Croneis 133

4. Our Endowment (Commemoration Address). By C. Judson Herrick 145

5. Science—Man's Liberator (Commemoration Address). By William E. Wickenden 154

6. The Application of Physics to Modern Hydrographic Surveying (Commemoration Address). By Herbert Grove Dorsey 164

7. An Annotated Check-list of Birds Recorded at Granville, Licking County, Ohio. By Ward M. Klepfer and William J. Taylor.... 187

GRANVILLE, OHIO

AUGUST, 1937

The University Bulletin is issued bi-monthly and is entered at the Post Office in Granville, Ohio, as mail matter of the Second Class

JOURNAL OF THE SCIENTIFIC LABORATORIES OF DENISON UNIVERSITY

The entire file of volumes 1 to 13 was destroyed by fire; no publications issued prior to 1907 are now available. Volumes 14 to date may be obtained from the editor at $2.00 per volume, with the exception of volume 15, the price of which is $1.00. Separate parts, as listed below, may be purchased at the prices indicated.

VOLUME 14

Articles 1-5, pp. 1-60; Nov., 1908.....$0.50
- Pre-Wisconsin drift in the Finger Lake Region of New York; F. Carney. 16 pp., 4 figs.
- An esker group south of Dayton, Ohio; Earl R. Scheffel. 15 pp., 6 figs.
- Wave-cut terraces in Keuka Valley, older than the recession stage of Wisconsin ice; F. Carney. 12 pp., 3 figs.
- A form of outwash drift; F. Carney. 8 pp., 1 fig.
- State geological surveys and practical geography; F. Carney. 6 pp.

Articles 6-10, pp. 61-188; April, 1909.....$1.00
- Fossils from the Silurian formations of Tennessee, Indiana, and Kentucky; Aug. F. Foerste. 56 pp., 4 plates.
- Studies on Babbitt and other alloys; 10 pp. J. A. Baker.
- A stratigraphical study of Mary Ann Township, Licking County, O. 28 pp., 15 figs. F. Carney.
- Significance of drainage changes near Granville, Ohio; Earl R. Scheffel. 17 pp., 2 figs.
- Age of the Licking Narrows; R. F. Mather. 13 pp., 5 figs.

Articles 11-16, pp. 189-287; June, 1909.....$0.75
- A spectrometer for electromagnetic radiation; A. D. Cole. 10 pp., 6 figs.
- The development of the idea of glacial erosion in America; F. Carney. 10 pp.
- Preliminary notes on Cincinnatian fossils; Aug. F. Foerste. 20 pp., 1 plate.
- Notes on Spondylomorum Quaternarium Ehrenb; M. E. Stickney. 5 pp., 1 plate.
- The reaction to tactile stimuli and the development of the swimming movement in embryos of Diemyctylus torsus Eschscholtz; G. E. Coghill. 21 pp., 6 figs.
- The raised beaches of the Berea, Cleveland, and Euclid sheets, Ohio; F. Carney. 25 pp., 5 figs.

Articles 17-18, pp. 289-442; November, 1909.....$1.00
- Preliminary notes on Cincinnatian and Lexington fossils; Aug. F. Foerste. 45 pp., 5 plates.
- The pleistocene geology of the Moravia Quadrangle, New York; Frank Carney. 105 pp., 27 figs.

VOLUME 15

Article 1, pp. 1-100; March, 1910.....$1.00
- Bulletin in commemoration of Clarence Luther Herrick.

VOLUME 16

Articles 1-3, pp. 1-120; June, 1910.....$1.00
- The metamorphism of glacial deposits; F. Carney. 14 pp., 7 figs.
- Preliminary notes on Cincinnatian and Lexington fossils of Ohio, Indiana, Kentucky, and Tennessee; Aug. F. Foerste. 81 pp., 5 figs., 7 plates.
- The abandoned shorelines of the Oberlin Quadrangle, Ohio; Frank Carney. 16 pp., 5 figs.

Articles 4-7, pp. 119-232; Dec., 1910.....$0.75
- Standardisation of well water in the vicinity of Granville, Ohio; Lily Bell Sefton. 5 pp.
- Chapters on the geography of Ohio; F. Carney.
  - Transportation; 11 pp.
  - Economic mineral products; 47 pp.
  - Glaciation in Ohio; 48 pp.

Articles 8-12, pp. 233-346; April, 1911.....$0.75
- The abandoned shorelines of the Vermilion Quadrangle, Ohio; F. Carney. 12 pp., 2 figs.
- Thermo-electric couples; A. W. Davison. 21 pp., 16 figs.
- The Mercer limestone and its associated rocks in the Newark-Zanesville region; Clara G. Mark. 47 pp., 2 plates, 5 figs.
- A study of the supposed hybrid of the Black and Shingle-oaks; Earl H. Foote. 13 pp., 4 plates.
- A case of pre-glacial stream diversion near St. Louisville, Ohio; Howard Clark. 8 pp., 4 figs.

Articles 13-17, pp. 347-423; July, 1911.....$0.75
- The Swasey Observatory, Denison University; Herbert C. Wilson. 5 pp., 4 figs.
- The contribution of Astronomy to general culture; Edwin B. Frost. 12 pp.
- The geological development of Ohio; F. Carney. 15 pp.
- The relief features of Ohio; F. Carney. 13 pp., 1 fig.
- Geographic conditions in the early history of the Ohio country; F. Carney. 20 pp.

VOLUME 17

Articles 1-4, pp. 1-201; March, 1912.....$1.50
- A geographic interpretation of Cincinnati, Ohio; Edith M. Southall. 16 pp.
- Strophomena and other fossils from Cincinnatian and Mohawkian horizons, chiefly in Ohio, Indiana, Kentucky; Aug. F. Foerste. 158 pp., 18 plates.
- Population centers and density of population; F. Carney. 15 pp.
- The climate of Ohio; F. Carney. 9 pp.

Articles 5-7, pp. 203-246; March, 1913.....$0.50
- The twenty-fifth anniversary of the founding of the Denison Scientific Association. 2 pp.
- The foundation of culture; C. Judson Herrick. 14 pp.
- Drainage changes in the Moots Run area, Licking County, Ohio; Harmon A. Nixon and Dexter J. Tight. 11 pp., 1 fig.
- Some pre-glacial lake shorelines of the Bellevue Quadrangle, Ohio; F. Carney. 16 pp., 3 figs.

Articles 8-10, pp. 247-373; March, 1914.....$1.00
- Lorraine faunas of New York and Quebec; Aug. F. Foerste. 93 pp., 5 plates.
- A comparative study of circular and rectangular Imhoff tanks; Theodore Sedgwick Johnson. 26 pp.
- Geographic factors in the establishing of the Ohio-Michigan boundary line; Constance Grace Eirich. 7 pp.

Articles 11-14, pp. 375-487; September, 1914.....$1.00
- A method of subdividing the interior of a simply closed rectifiable curve with an application to Cauchy's theorem. F. B. Wiley and G. A. Bliss. 14 pp., 3 figs.
- The influence of glaciation on agriculture in Ohio; Edgar W. Owen. 4 pp, 1 fig.
- The Locust Grove Esker, Ohio; James D. Thompson, Jr. 4 pp., 1 fig.
- Notes on Agelacrinidae and Lepadocystinae, with descriptions of Thresherodiscus and Brockocystis; Aug. F. Foerste. 88 pp., 6 plates.

VOLUME 18

Articles 1-3, pp. 1-284; December, 1915.....$1.75
- Proceedings of the inauguration of President Chamberlain. 54 pp.
- Denison University presidents; William Hannibal Johnson. 5 pp.
- The fauna of the Morrow Group of Arkansas and Oklahoma; Kirtley F. Mather. 226 pp., 2 figs., 16 plates.

Articles 4-7, pp. 285-378; December, 1916.....$1.00
- Notes on Cincinnatian fossil types; Aug. F. Foerste. 71 pp., 7 plates.
- The shorelines of glacial lakes Lundy, Wayne, and Arkona, of the Oberlin Quadrangle, Ohio; Frank Carney. 6 pp. 1 fig.
- The progress of Geology during the period 1891-1915; Frank Carney. 8 pp., 4 figs.
- The abandoned shorelines of the Ashtabula Quadrangle, Ohio; Frank Carney. 24 pp., 4 figs.

VOLUME 19

Articles 1-4, pp. 1-64; April, 1919.....$0.75
- Echinodermata of the Brassfield (Silurian) formation of Ohio; Aug. F. Foerste. 30 pp., 7 plates.
- America's advance in potash production; W. C. Ebaugh. 14 pp., 2 figs.
- The use of outline charts in teaching vertebrate paleontology; Maurice G. Mehl. 8 pp., 1 fig., 4 plates.
- Some factors in the geographic distribution of petroleum; Maurice G. Mehl. 9 pp., 2 plates.

Articles 5-8, pp. 65-146; September, 1919.....$0.75
- Notes on Isotelus, Achrolichas, Calymene and Encrinurus; Aug. F. Foerste. 18 pp., 6 plates

SCIENCE AND THE COLLEGE

CAREY CRONEIS (D. U., '22)*

Address given at Denison University, April 16, 1937, in Commemoration of the Semi-centennial of the Founding of the Denison Scientific Association.

It gives me great pleasure to have been asked to return to Denison for this occasion, if for no other reason than because so many of the instructors at whose feet I reverently sat are still with us here today. For despite my various educational wanderings, I am certain that they are the best teachers I ever had. Their Committee has asked that my address be sufficiently erudite to interest the faculty, yet not formal enough that it prove too annoying to the student body. That is what they requested, but I suspect them of meaning, let it be instructive enough so that the students will be interested, and informal enough so that the faculty will not be too bored. But I have little compassion for faculty members, since by deliberately choosing our profession we have indicated that we are prepared to listen, or at least appear to listen, to any lecturer, even should he prove as boring as we are. My sympathies, however, are with the students. When I was in school we used to say: "If all chapel speakers could be laid end to end—wouldn't that be nice?" In spite of a changing, chaotic world, I have faith that this is an almost unvarying student reaction. Accordingly, I shall spare you, and the faculty, as much as possible.

Fifty years ago today, when the site of my own University of Chicago was still a wild onion swamp, the Denison Scientific Association held its first meeting in Professor Clarence Luther Herrick's old College Hall lecture room. Professor Herrick had been graduated from the University of Minnesota in 1880, finishing his college course with honors in three years. Even as an

* Professor of Paleontology, The University of Chicago.

undergraduate he had published five papers, one of eighty-four pages and twenty-one plates, the illustrations for which he had prepared himself. After having spent a profitable year in Germany, chiefly in Leipzig, Professor Herrick was called to Denison in 1884. Although only twenty-six years of age he was already a man of considerable scientific reputation. It was not surprising, therefore, that he should be given the so-called "settee" of the natural sciences.

Shortly after his arrival, Denison advertised its fine points as follows:

> "The college has eleven professors and instructors, well-equipped chemical, physical and biological laboratories, and a large and excellent library. The productive endowment exceeds $300,000.00, the instruction is thorough and the expense is low. Those who can not take a full course are permitted to take special studies when they can do so with profit to themselves and without injury to others. School year from September 9, 1885 to June 4, 1886."

But Professor Herrick made the most of Denison's then slender resources, and demonstrated that through men, not equipment or endowment, institutions grow great. Prior to coming to Granville, he had had a relatively easy time in finding a place of publication for his voluminous writings. Once in Ohio, however, he decided that it would be unlikely that his papers would still find ready publication in Minnesota, where he had had his earlier connections. As a consequence, and with characteristic energy, he founded the *Bulletin of the Scientific Laboratories of Denison University*, the first volume of which was published in December, 1885. Herrick not only assisted in the printing, but he was able to engrave all of the plates himself, since in his earlier work in Minnesota and in Germany he had familiarized himself with the art of lithographing. He utilized the resources of W. H. Kussmaul's job printing shop in Granville, and saw to it that pages of scientific articles were set up whenever the presses were momentarily free of copy for grocery and dry goods ads. The expense of the first volume was borne in part by Herrick and some of his faculty associates, by liberal trustees of the college, and by "liberal Baptists" of Dayton, Columbus and Cleveland.

C. L. Herrick, aged twenty-seven, and August F. Foerste, later one of the world's greatest paleontologists, but at that time a sophomore twenty-three years old, were the sole contributors to Volume I. It was characteristic of Herrick to do the first things first. Denison needed, and he himself required a journal, so he founded one. Then he saw the need for a scientific association to support it, so he established that too. The ordinary procedure, of course, has been to found a scientific association which after a number of years of semi-moribund existence may finally have the temerity to publish a journal. But Herrick was not an ordinary man. Recognizing that the journal had had a sort of left-handed birth, he wished to legitimize it by providing a parent. Accordingly on April 16, 1887, he called together the twenty-seven men who became the charter members of the Denison Scientific Association. Five of these original members enlisted from the faculty, the others were students. They were all young, most of them in their twenties, but a great many were to attain national, and even international distinction. Of the group, thirty percent were later listed in "Who's Who in America." A half dozen were starred men in "American Men of Science," and two of them became members of the National Academy of Science. As far as can be ascertained, practically all of the twenty-seven gained some real distinction in life, interestingly enough some of them in fields quite distinct from science. Several became clergymen, a number were college professors in subjects other than science, two were presidents of a state university, and one, Professor W. H. Johnson, became a distinguished editorial writer.

Herrick's influence remained strong on all of these early associates. He was the central figure in a group whose members considered themselves his disciples. As sometimes happens, at least two of his original twenty-six followers were so inspired by his enthusiasm that they gained even greater distinction in science than did their leader. Professor W. E. Castle of Harvard, a member of the National Academy, for years has been regarded as one of the world's greatest geneticists. Professor C. Judson Herrick, of The University of Chicago, a brother ten years

younger than Clarence Luther Herrick, has by many been considered the world's foremost neurologist. He too is a member of the National Academy of Sciences. Indeed, most scientists feel that the very founding of the science of neurology, in the modern sense, is due to the activity of the Herrick brothers. Entirely through their efforts there came into being the *Journal of Comparative Neurology*, which was for a time edited at Granville, and with which C. J. Herrick has been connected as the managing editor for well over forty years. The elder Herrick also interested W. S. Tight in problems of drainage changes induced by glaciation, so much so that Professor Tight finally became recognized as the leading authority on this subject; and many of the later publications in this field stem at least indirectly from his early efforts. Somewhat later Herrick fired Douglas Johnson's interests in physiography with such results that Professor Johnson, of Columbia, and another member of the National Academy, is generally regarded as the world's foremost authority on shore processes.

In a very real sense, then, Denison's little science nucleus, with C. L. Herrick as its mentor, may be compared, and favorably too, with the Agassiz or Shaler circles at Harvard, or the famed University of Kansas group under Professor Williston, the latter leader having been active at almost precisely the time that C. L. Herrick was at the height of his inspirational career.

Immediately after the issuance of the first volume of the *Bulletin of the Scientific Laboratories*, but before the founding of the Scientific Association, Herrick showed his leadership in still another way. He founded one of the earliest summer schools of natural history in North America. In 1886 he took a number of his students and associates on a trip, largely biological and geological in character, to the northeastern shore of Lake Superior. Doubtless it was on this pioneer expedition that some of the plans for the Denison Scientific Association were formulated.

In 1889 Professor Herrick left Granville to become professor of biology at the University of Cincinnati, although he returned to his former position at Denison in 1892. While he was at Cincinnati, Volume V of the *Bulletin* was published. Herrick,

no longer in Granville, nevertheless contributed largely to the funds needed for publication. In this connection it is interesting that the remainder of the sum required was contributed by four members of the First Baptist Church in Dayton. These were the three famous Thresher brothers, and E. J. Barney. The ugly, unnecessary, actually non-existent conflict between science and religion has never reared its head at Denison.

By 1890, when this fifth volume of the *Bulletin* was issued, its exchange list was already international in character. The following foreign countries were represented by natural science or philosophical institutions whose publications came to Denison in exchange for its *Bulletin:* Argentina, Australia, Austria, Belgium, Bohemia, Canada, Denmark, France, Germany, Ireland, Italy, Japan, Norway, Portugal, Russia, Spain, Sweden, Switzerland. In addition, all the important scientific institutions in North America were on the list. Thus, at an early date, when most of the small colleges were gingerly and fearfully toying with the idea of teaching sciences thoroughly, Professor Herrick's foresightedness made it possible for the college to build up a really notable scientific library. Today the *Journal* of the Scientific Laboratories* is sent to 125 foreign institutions and approximately the same number of colleges, libraries, and academies of science in North America. In exchange there are received about 250 foreign, and approximately 300 domestic publications or serials. Many of these are government bulletins, experiment station records, memoirs of national and provincial academies of science, and the like. It is extremely doubtful if any college of anything like Denison's size has been equally favored in acquiring these essential tools of the scientist. Now with the completion of Denison's new library it will be possible to make all of this vast store of scientific information readily available to students and faculty alike. How C. L. Herrick would have loved to have seen the manifold results of his efforts! As a matter of fact, although he is long since dead, his brother, a youthful, black haired man of nearly seventy, and his remarkable mother,

* To comply with Governmental postal regulations it became necessary to change the name from *"Bulletin"* to *"Journal"* in 1920.

alert at well past the century mark, do rejoice in the ever widening circle of his influence, which has continued through his students and their pupils.*

On one of the gates to the campus of Denison University there is inscribed this quotation:

> "The heights by great men reached and kept
> Were not attained in sudden flight;
> But they, while their companions slept,
> Were toiling upward in the night."

This quotation might well have been written concerning the elder Herrick himself, since it was said of him that his light was the last one out in the town of Granville, and that students going to early classes usually found that Professor Herrick had already been out in the field on a collecting trip. Such extraordinary enthusiasm drove him at last to excesses which his body could not stand, and he became afflicted with lung trouble. He therefore went to New Mexico in order to find a more congenial climate, but instead of resting he was pressed into service as president of their State University, at Albuquerque. He occupied this position until 1901 when continued ill health caused him to resign in favor of his favorite former student, Professor W. G. Tight, who had been given the chair of geology at Denison when Herrick left Granville.

Herrick always was intensely interested in psychology and wrote many papers on this subject. Upon his return from the University of Cincinnati in 1892 he founded still another journal at Granville, known as the *Denison Quarterly*, for it was his idea that not only the scientific papers written at the college but those of a general nature ought to have some means of publication. Thus Herrick gave the lie to the idea that great scientists are apt to be one-sided in their interests. He knew that "lan-

* *Editor's Note.* It will interest the friends and old students of Dr. C. Luther Herrick to know that his widow, Alice Keith Herrick, still makes her home in Granville, Ohio. Their son, H. N. Herrick, resides in Berkeley, California, and is employed in the Research Department of the Standard Oil Company in San Francisco. Their daughter, Mabel Herrick Brush, lives on a ranch near San Bernardino, California; and a second daughter, Laura Herrick, was a member of the library staff at The University of Chicago at the time of her death in 1931.

guages are the keys to the sciences," and he believed that there also was a strong philosophical aspect to the sciences which should not be neglected. Therefore, in spite of his great popularity, and the prominence he gave to the scientific work at Denison, there is no indication that any of the non-scientific departments were jealous of his successes. Probably this was because he was nearly as much interested in their work as he was in his own.

Herrick died in 1904 at the age of 46. He was the author of more than 200 papers, many of which were of monographic character, and they covered a half dozen different fields. In his short scientific lifetime, most of which was marked by illness, he produced results which would have done credit to a score of active workers. Today his scientific children, even unto the third and fourth generations, are actively carrying on his tradition.

It may be safely said that we enjoy a definite inheritance from the many great teachers who have adorned the faculties of our small colleges. This fact is probably responsible for a situation peculiar to not a few of these institutions, namely, that they have been able to train men distinguished in many lines, and to train them as well and proportionately in even greater numbers than the so-called great universities. If one investigates each small college's contribution to the field of science, he finds that its distinction in large measure directly or indirectly results from the teaching of some one great scientific leader and his followers. *The gene of scientific greatness passes from teacher to student through many college generations.*

In the fifth edition of "American Men of Science" (1933), the records of the 250 men newly starred for eminence in science have been analyzed. Thirty-four schools were listed as giving two or more of the bachelor's degrees to men in this group. Of the 250 distinguished scientists, 19 received their degrees from Harvard, 13 from Chicago, and so on down the list. Seventy-nine schools, which were represented by a single recipient of the bachelor's degree, were not specifically named. Denison contributed three men to the list. Swarthmore with three, and

Amherst with five, were the only other small schools mentioned, and both of these have had a much larger male student body. Denison's sterling record can better be evaluated by pointing out that a great many of the large universities of the country were not represented at all. Moreover, Yale University educated only five of the scientists, and Johns Hopkins, Pennsylvania and Wisconsin two each. Such a record as this is certainly not entirely a matter of chance. Two of the three men starred from Denison were honored in the field of geology. This, I think, has resulted from the fact that since Herrick's day there has always been an inspirational teacher occupying the chair of geology. Following Herrick, in order, these great teachers were: Tight, Watson, Carney, and Mather; and Professor Wright is today continuing in their fine tradition. As a result of the inspirational leadership of all these men several score of Denison graduates are now making fine records for themselves as professional geologists.

Suppose we now examine the record of the 633 men who have been honored with fellowship in the Geological Society of America. We find that 151 institutions in the United States and Canada have been responsible for their undergraduate training. Again Harvard heads the list with 46 fellows, but Denison stands phenomenally high with seven. The uniqueness of this position may be realized when we consider that Columbia has contributed but 13 of these fellows, and that only 23 of the 928 American colleges and universities rank higher than Denison in this list. Moreover, all of the twenty-three are large schools with student bodies of from twice to twenty times Denison's enrollment. Denison has contributed more geologists to the fellowship of the Geological Society of America, for instance, than such well-known schools as the Universities of Illinois, Michigan, Missouri, and Pennsylvania.

I have been speaking particularly about geology because I am most familiar with the situation in this field, but Denison's sterling record in the sciences is by no means confined to this subject. Several years ago the two best sellers in the non-fiction list were both written by Denison men. One, you may remember,

as "Why We Behave Like Human Beings," by the anthropologist, George Dorsey. The other was "The Brains of Rats and Men," by Dr. C. J. Herrick, to whom I have earlier referred. Moreover, all of the scientific departments not only have made their great contributions in the past, they are continuing to make them this very day; and, although I have been asked to talk on science, I must add that all Denisonians are equally proud of the training their alma mater has provided in non-scientific fields. In fact, I have a feeling, shared by many educators, that since a college is a close knit community of teachers, fine leadership in one department is "catching," and will spread to the others like some contagious disease. When this at last happens even the students, notoriously immune, are likely to be infected and possibly to their chagrin develop an epidemic of sound learning.

President Hutchins, of The University of Chicago, in a recent speech, said "In a university research sometimes is employed as a veil or a cloud into which the individual may disappear when interrogated about his work. To the question 'What are you doing?' the single answer 'research' is used with devastating effect. No further questions can be put without invading the professor's constitutional rights." He went on to say, "Science, I venture to think, should not be a veil or a cloud either. Many people, even scientists, have a misconception of what science is. And many people are doing sloppy work in its name. Nor should science be used for an excuse for ignorance of everything else. It is not an excuse for denying the existence of other types of knowledge or for dogmatic expression on subjects not susceptible to scientific investigation."

In general I think the members of the scientific staff at Denison would agree. They have not used science as a sort of *sanctum sanctorum* into which they might retire. In fact, one of the strong points of early scientific training in a college, as opposed to similar training in a university, is the simple fact that in the small school the scientist is available to the student, and the student is important to the scientist. In most cases college scientists have also been men of a real sense of humor. A pop-

ular song of the moment has a line to the effect that "humor is death to romance." As a matter of fact, the *lack* of humor is probably more deadly than anything else. In more or less factory-like larger institutions humor may sometimes be lacking in the laboratories. But I have a feeling that all great scientists, or great men in any other field, for that matter, have been amply blessed with the gift of humor. It is certain that Professor Carney was, and from my own experience I know that many of your faculty are.

I cannot conclude without warning the would-be scientist that he too must be prepared to develop his sense of humor if he persists in his studies, for eventually he will be blamed for practically every mishap under the sun. Already the scientist is chided for all of our wants, and cursed for all of our excesses. A recent publication, although bogged down with the weight of its own excess *paragraphs*, even takes the scientist to task for his use of excess *words*. Some educators are actually of the opinion that the liberal arts college should now give complete dominance to the social sciences, the theory being that since the natural sciences have bewildered the world with their horrible economy of abundance, it remains for the social sciences to find the way out of the dilemma.

Recently Norman Foerster, of the University of Iowa, has described our time as a "sick century." Its disease might be called "chaos," the symptoms being bewilderment, drifting, loss of standards, and of appetite for life. Foerster has said that the disease originates as a germ of doubt, and passes by easy stages from general scepticism to self-destruction. He thinks the disease is somehow related to the decline of the liberal arts colleges within larger universities, and of the independent small colleges. Only a few years ago the majority of students were given four years of so-called cultural courses, but now the liberal arts college is subordinate, he says, to vocational knacks and professional skills, and is actually crowded out by teacher training, commerce, journalism, library science, and courses on how to be a gymnasium instructor. Small colleges as a result are being overwhelmed by state universities and by two-year col-

leges. Today, therefore, the desperate problem of the small college is not that of recruiting students, but rather of showing why any student should enroll at all. Perhaps the liberal arts colleges can find a new reason for existence in the illness of the twentieth century mind. The cure, Foerster thinks, may not be complete until we have built up a metaphysics, or a theology as impressive as those of ancient Greece or those of the Middle Ages. Foerster, like Hutchins, therefore, would put less importance on fact collecting and more on reflection, and they both would like to supplant courses in radio advertising, for instance, with intensive study of Plato and Aristotle.

Of course, doctors always disagree, but I should like to suggest another remedy. I realize that it is too simple a treatment to make the headlines, so simple in fact that it may be just what is needed. I propose that liberal colleges do nothing more radical than continue to do what they have been doing with distinction. Let the so-called great institutions experiment. There is no royal road to education, no curricular panacea, no scholastic cure all. Give me a few men of the Herrick stamp, and you can have all of the educational schemes since the turn of the century. In short, it seems to me that small colleges of the type of Denison, which have for decades made an important contribution to science, and to education in general, would be doing themselves and future generations a distinct disservice were they completely to abandon the tactics which they have for so long followed with outstanding success. I am as distrustful of a curriculum based *chiefly* on metaphysics as I am of one *solely* predicated on or designed for teacher training. Yet there is a wholesome type of metaphysics which colleges like Denison instill in their students without feeling compelled continually to mouth the term. The eminent scholar, J. Edgar Goodspeed, who was a freshman at Denison when the Scientific Association was founded, became not a scientist, but a noted essayist, humorist, and the outstanding modern translator of the Bible; yet only last week he told me that even after fifty years he gets a thrill whenever he thinks of the work he had under C. L. Herrick, and that he is actually emotionally stirred and philosophically re-

vitalized whenever he visits Granville. This is at least a sort of metaphysics. Probably it is metaphysics with a capital "M." At the college level, the sterling American small schools of the Denison type are most likely to provide it for the embryo scientist, and, doubtless more important, for the embryo citizen as well.

OUR ENDOWMENT

C. JUDSON HERRICK (D. U., '91)*

Address given at a Symposium on Science and Human Welfare, held at Denison University, June 12, 1937, in Commemoration of the Semi-centennial of the Founding of the Denison Scientific Association.

Our endowment; this subject is not news to the alumni; you have heard about it before. I suggest that we now take an account of stock, an appraisement, of the endowment that we already have. This may help us to formulate more clearly what we want next.

I am not good at figures, so we shall pass over the statistics of invested funds, buildings, grounds, equipment, and current income. In addition to all this we have another endowment that neither moth nor rust can corrupt nor financial panics destroy. We have an inheritance of tradition, of ideals cherished and realized, of actual accomplishment in refining the character and guiding the careers of generations of men and women. The intangible influence of these people, our trustees, our faculties, our students, represents an asset of far more worth to this college than all its tangible property, an indestructible endowment trust, whose yearly increment is much more secure and rapid than ordinary compound interest.

The Denison Scientific Association, whose second half-century is now beginning, is only one of many items in the docket of this great trust which is ours by right of inheritance and undisputed possession. At the birth of this Association I was one of the litter of twenty-seven cubs whose eyes were opened to the world of science on that memorable evening of April 16, 1887, when we signed our names to the roll of Charter Members. Mr. Wallace H. Cathcart, our trustee, is the only survivor of that roll who is now connected with Denison, and as a freshman he out-

* Professor Emeritus of Neurology, The University of Chicago.

ranked me, for I was the youngest, the runt of the litter, only a prep. My sister, Mrs. C. L. Herrick, was the efficient nurse, whose attendance and encouragement contributed much to the vigorous growth of the infant society.

Of the founder and father of this Association—his favorite brain-child—I should like to speak at length, but need say little, for Professor Croneis' address on the recent anniversary date was a sympathetic and understanding tribute to the person and achievements of that versatile genius, my big brother. He was all that an elder brother should be to me, and he was more than that; he was my teacher, and to the inspiration of that teaching and that example I owe my highest satisfactions in the pursuit of science and in what Stevenson so happily calls "the continent art of living well."

It is more difficult to draw an adequate portrait of the other parent of this organization, our alma mater. From the invisible genes which she carries in her body have sprung this and numerous other progeny, her children, whose creative vitality constitutes the true wealth of this college. Looking backward fifty years the evaluation of these resources is perhaps easier now than it was then.

At about that time this college was reborn. This was not a resurrection from the dead. When I first set foot upon this campus our institution was far from moribund; it was very much alive in the vigor of young middle age. Yet within one decade from that date this healthy life was rejuvenated and redirected. What is the secret of this miracle?

In 1885, when I studied rhetoric, Latin, Greek and mathematics in these halls, we had good teaching in the sound conservative tradition of the time. Then something happened. A revolution in the ideals and method of education which has since swept the educational world began on this hill-top almost a generation in advance of the general movement. Instead of pouring knowledge into passive and more or less resistant minds and trying to hold it there by drill-master pressure, the new effort was directed toward quickening these minds into eager search for knowledge.

We learn by doing things, not by hearing or reading about them. Children, like their elders, must act things out in some fashion before they can understand them, for action comes before thinking in the development of the learning process, and the thinking which must precede action in adult efficiency still carries over some of the dynamic qualities of its prerational antecedents. All learning is growth; it is an organic process, and active exercise of his own constructive faculties by the learner is as essential here as in the development of muscular power and skill. Education, as so often pointed out, is not pouring something in; it is drawing something out, something made actively by the learner himself. This was not a new idea fifty years ago, but the actual practice of it in revision of curricula and the aim and method of pedagogy was revolutionary.

The founding of this Association was the overt expression of the internal activity of this ferment in the academic realm. The key-note of the movement from its inception was, "Find it out for yourself; take nobody's word for it." The membership was composed chiefly of undergraduate students and the primary function of the organization was evidently the stimulation of interest and training in the method of science. The immediate success of the enterprise can be measured in two ways. First, by the surprising number of contributions to knowledge deemed worthy of publication made by the students themselves and by junior members of the faculty; and, second, by the reflex effect on the educational policy and actual class-room practice of the college as a whole. The significance of this second point should not escape us.

It is a remarkable fact that nearly half of the student charter members came from the classical, not the scientific, course and two of the five faculty members were teachers of Latin (Chandler) and Greek (Johnson), respectively. And in the immediately following years the humanities participated actively in the persons of Colwell (Greek), McKibben (Romance), Willis Chamberlin (German), and several others. Thus the scientific spirit infiltrated every department and all coöperated with enthusiasm and remarkable results.

This did not happen by accident, nor was it the work of any one man. If the soil had not been good and the seed planted had fallen on stony ground, the growth which we enjoy today would never have begun. This fifty-year-old youngster whose birthday we celebrate had a maternal inheritance whose characteristics have been expressed generation after generation in liberal and enlightened administration, too honest and courageous to be restricted by sectarian dogma or to allow faculty or students to be so fettered.

From the beginning of this spectacular growth of scientific activity it was generously supported by the trustees, most of whom have always been loyal and active members of the Baptist Church, and time after time when deficits and other crises have arisen these men have met the emergency from their own personal funds. This liberal support was never at the expense of other interests, for progress in the humanities has been equally well sustained and indeed has been accelerated by this productivity in the scientific field.

This was the spirit of the early 1880's. Under the influence and inspiration of two progressive teachers of science, Hicks and Osbun, the scientific course was established and made respectable. This required ten years' time. And before that, throughout the administrations of E. Benjamin Andrews, Samson Talbot, and their illustrious predecessors fidelity to truth and tolerance of every honest effort to attain it was knit into the vital fabric of this institution. The academic soil was thus prepared and fertilized, so that when new seed was planted in the middle of that decade conditions were favorable for growth and radical reorganization, not only in the science courses, but in all the others as well.

I was a member of the Denison faculty during the second decade of the life of the Scientific Association. I was regularly teaching evolution in all of my classes, and during the first half of that same decade the President was teaching Evidences of Christianity from a textbook—his own—which vigorously attacked this doctrine. And there was never, so far as I know, the slightest friction about it. That was in the 1890's.

Now, what is the peculiar quality of this scientific spirit which was infused into Denison in the 1880's—what is the secret of its quickening power? Science is not an inert mass of knowledge; it is a method of acquisition of knowledge. It is a vital, growing thing, a product of human effort, and saturated with human values. Science as a human achievement carries in its vital texture something of the quality of the human instruments by which it is wrought. It is inevitably so, and properly so.

There is an ancient dogma handed down from metaphysical tradition of unknown antiquity, and complacently accepted by most philosophers and men of science alike, which declares that "Science knows no values." This is a mischievous and libelous caricature and is responsible for a world of misunderstanding and unseemly friction between science and the humanities. There is no substantial ground for conflict or rivalry here. Our aims are the same. It is the same humanity whose life we strive to enrich and to ennoble. The difference lies only in the technique of our operations. We are specialists in different fields, we cultivate values, all of us, and in the upshot the same values.

The values which science cultivates and enjoys are not mere by-products of its activity. I am not speaking here about the rewards and emoluments of invention or the clever gadgets that have contributed so much to the comforts and profits of our generation, but about values of a different order, about the satisfactions which are inherent in scientific work, the joy of discovery and triumphant conquest, and the enrichment of human life which comes from wider horizons of knowledge and deeper insight into the meanings of things. These are not mere ornaments which bedeck the body of science. These values are the vital breath of science, for without this motivation scientific research worthy of the name would perish.

One day when I was a little kiddie my father was dressing me. As he pinned up my clothes, he asked, "Shall I put in the pins as usual or the way the soldiers did when I was in the army? If you pin through the skin it holds better." I had not yet achieved a fortitude up to my father's military standard and

the pins were put in as usual. Yet fortitude not less heroic than this test must be achieved if one hopes to win success in life's battles, and the exactions of scientific research require that the student's chosen program invest his person more intimately than his clothing. The motivation of his research and the ideals for which he works must be woven into his vital tissues so as to become an organic part of him. Science, like religion, is a mode of life, not a vesture to be worn on Sundays or during business hours.

The scientific method demands that belief and conduct be regulated by actual experience with things as they are, not by wishful thinking, prejudice, tradition, authority, or irrational dogma. Natural science, of course, has no monopoly of this method, which is older than human nature. The great contribution of modern science to human welfare and progress is the popularization of this practice by demonstration of its efficiency and the codification of the rules for its successful application. That is all we claim for it; and that is enough to have set in motion successive waves of industrial revolution, a far more fundamental revolution in educational practice, and a liberalizing of the minds of men in their attitudes toward all of the minor and major problems of human adjustment.

This, I repeat, is the greatest contribution of science to human welfare. We have gone far in this direction and the goal is not yet in view. But we have failed, miserably failed, to apply this scientific method in the larger field of our social relations one with another. The most serious disasters of human history and the most acute problems with which the very sick civilization of today is confronted have arisen from failure to apply the scientific method or even common horse sense to the elementary problem of how to keep the peace with our neighbors. We continually allow irrational prejudice, pride, egotism, provincialism, nationalism, political expediency, greed, and lust for power to overwhelm common sense and the plain teachings of past experience in all our social adjustments from petty family squabbles to wars of world-wide destructiveness. A well validated social science may be a dream of the far future; it may be a long time

before most of us can learn to love our neighbors as ourselves; yet we already have all the experience that we need to learn the simple lesson that a stable and productive society can rest on no other foundation than a voluntary renunciation of some personal and national advantages in the interest of general welfare. Is human nature too dumb to take the most essential and obvious steps for its own preservation?

Life as we mortals have to live it is just one thing after another. The one thing is getting; the other is giving. The rules of this reciprocating exchange are very fundamental. These rules come to expression in all physiology, in all education, in all commerce and industry, in all morals and in all the amenities of life. There is no possibility of evasion or beating the game. Our problem, then, is to see that we get what is most worth while and so to arrange our giving that both donor and recipient will profit by the transaction. Our skill in resolving this problem is the measure of success in life and the satisfactions achieved and indeed in the preservation of our civilization.

In an advanced human society coöperation conducted with honor and righteousness is not a frill with only decorative value. It is as essential to the survival and enhancement of civilization as are food and business efficiency. Without these qualities the social fabric rots and falls apart or reverts to an ape-and-tiger plane of life in which the higher cultural values are extinguished. A natural system of practical morals could be elaborated on a sound scientific basis from one simple principle: Moral satisfaction, the noblest of our values, arises from establishing right relations with our fellow men, and these values are enhanced by further improvement of these relations. The right relations are those which are mutually advantageous. This conclusion is drawn, not from philosophy, theology or ethics, but from science; for, as Dr. Karl T. Compton points out:

"Modern science has given mankind, for the first time in the history of the human race, a way of securing a more abundant life which does not simply consist in taking it away from some one else. Science really creates wealth and opportunity where they did not exist before. Whereas the old order was based on competition, the new order of science makes possible, for the first time, a cooperative creative effort in which everyone is the gainer, and no one the loser."

The University of Chicago has very recently given us an excellent illustration of the right way to apply the scientific method to acute problems of social administration. About two years ago one of the prominent merchants of that city charged that The University of Chicago was fostering doctrines subversive of American ideals and institutions, and he demanded suppression of this radical teaching. After much scandalous newspaper notoriety and a state legislative investigation, with of course no useful result, the matter apparently had reached stalemate. The charges were not withdrawn and the University insisted on its right and duty to preserve its policy of freedom of study and teaching of all aspects of controversial questions. Now comes the announcement that this dissatisfied merchant has contributed over half a million dollars to The University of Chicago for the endowment of a Foundation for the Study of American Institutions. The purpose is to find out the facts before forming conclusions, to learn before teaching. This is the right solution of the problem presented by a bitter controversy, an application of the scientific method to an acute social problem.

In a university freedom of study and freedom of teaching form the only secure foundation, not only for all sound scholarship, but even more for the application of the fruits of scholarship to the advancement of human welfare. We have seen within recent years the utter destruction of this freedom in several European countries. All teaching from primary schools to universities is controlled by the dictatorial power of the state in the interest of propaganda of dogma. This very effective political instrument has been so drastically applied as to wreck the entire educational system in the interest of political expediency. The tradition of sound scholarship built up by centuries of struggle has been thrown into the discard. This intellectual and moral endowment, upon which national efficiency ultimately depends, has been summarily and ruthlessly destroyed, and the cultural advance of some of the most progressive peoples on earth has been arrested with resulting reversion to a type of modern barbarism whose threat to the stability of our civilization

is dangerous just in proportion to the skill with which the resources of science and the technique of mass psychology are employed in its armament.

We in this country are not immune to the world-wide spread of these subtle influences which are corrosive of those ideals of political freedom and encouragement of personal liberty of thought and action upon which our Republic was founded and which form the ultimate basis of our national welfare. Our educational institutions, public and private, from kindergarten to university, provide our strongest bulwark against this recent trend toward abdication of personal rights and responsibilities in favor of some dictatorial control by special interests. The freedom which we claim as our birthright can not be preserved by surrender either to the conservatives who would suppress inquiry and teaching opposed to their traditions, or to those radicals who can learn nothing by the past experience of the race and try to foist upon us visionary schemes of social and political reform. What we need here is tolerance, courage to make experiments, and, what is more rare, courage to abandon those experiments which experience shows are faulty before it is too late to correct the error.

Denison has always stood stanchly for this sort of freedom. This is our heritage from the past, the most valuable endowment that we have. It is ours because we made it ourselves. It is a living thing that grew up out of our own soil. It cannot be taken away from us. It can be lost only if allowed to perish from neglect. And of this danger we see no sign.

SCIENCE—MAN'S LIBERATOR

WILLIAM E. WICKENDEN (D. U., '04)*

Address given at a Symposium on Science and Human Welfare, held at Denison University, June 12, 1937, in Commemoration of the Semicentennial of the Founding of the Denison Scientific Association.

Is science moving too fast for man? Who would have dreamed thirty years ago of raising such a question? Yet only recently a prominent English churchman asserted that the whole world would be better for a ten-year moratorium on all scientific inquiry and all technical invention—a breathing space in which economics, ethics, morals, laws and religion might have a chance to adjust themselves to this baffling new age.

Of course the reverend gentleman did not want to put all scientists, physicians and engineers out of business at one stroke. Without them the whole structure of society would crash around our heads, and when the few survivors had pulled themselves out of the ruins their life would be much like that in rural Russia under the Czars. Civilization has been called "man's greatest show"; as in the theater, the show must go on; for unless technicians keep society going, evolution may have its job to do over again.

But what of the advance of knowledge? Can society trust science with a free rein? There have been times a plenty when science has clashed with theology, but it is a new thing to have an issue raised between science and human welfare. No one worried much over the matter as long as science lagged rather than led. Religion, law, commerce, agriculture, the art of healing, and the art of war—all have had their professionals since the dawn of history; but science until 200 years ago was almost wholly a pursuit for amateurs. Like placer mining, here and there a solitary prospector washed an occasional nugget of truth out of

* President, Case School of Applied Science.

the coarse gravel of everyday experience. Few of these nuggets were coined into useful forms and put into general circulation. Most of them were hoarded for a time, then lost again to wait a thousand years for some new explorer to rediscover them. The Chaldeans, the Egyptians and the Greeks knew vastly more about astronomy than the best minds of Europe in the 17th century, who haled Galileo before the Inquisition under threat of torture.

Science never got on until it ceased to be merely an amateur interest, until men of special gifts began to make the winning of knowledge their major occupation. The pioneers of research had to learn not to be content with nuggets washed out of everyday experience, but to mine the hidden veins of truth and to separate the finely dispersed gold from base ore by experiment, analysis and verification. Science began to grow when observers took to preserving detailed records, to pool and criticize their discoveries, and to mill their gold into the coinage of everyday life.

Everyone knows that this cumulative science of the last 200 years, as contrasted with the casual science of the ancients, has been very disturbing to inherited patterns of thought. To be modern means to believe in progress—that if life isn't getting better, at least it ought to be; that our children have a right to a better chance than we; that mankind will not inevitably repeat all its past errors; that civilization may falter, but will ultimately consolidate and hold its gains. It was not so with the ancients, who believed that humanity was in a continuing or even a progressive state of decline. The good days for man were in the legendary past. The longed-for messiah was not to be a discoverer, a creator, but a restorer of man's lost estate. It was a depressing doctrine, tinged with futility.

Men of the middle ages looked upon life as a hard experience whose only reward was to be found in another world. Sainthood was the goal of all striving. Nature and the flesh were the soul's enemies. Truth was to be sought, not through discovery but in the lore of the ancients. If you were curious about nature, you consulted Aristotle. Invention was a casual and tedious matter of trial and error. The tools of one generation were

passed on to the next without change. The art of making a living remained virtually static, from the times of Caesar to those of the Pilgrim fathers.

Into the twilight of mediaeval pessimism science brought a new conception, a clear and steady beam of hope that man might be in large degree the master and not the victim of his fate. Streaks of dawn began to appear toward the end of the 13th century. Alchemy and black art, groping blindly, taught men to experiment. Crude invention, such as printing from type, prepared the way for the spread of knowledge. Bold spirits like Columbus crossed the great seas and dispelled the nameless terrors beyond their horizons. The religious revolt taught men to question and to doubt.

Three centuries of twilight, and then full dawn. Harvey discovered the unity of the body in the circulation of the blood. Kopernik, Kepler and Galileo gave back to man a rational picture of the universe. Francis Bacon taught the new art of scientific thinking and Newton in his grand synthesis of gravitation linked the whole cosmos from atoms to stars in one vast mechanical unity. At last man had a chance to think of Nature as something harmonious and dependable, something to understand and coöperate with, and not as a mere battleground of demons and angels contending for the possession of man's soul!

Science has taught men to believe not only that progress is possible, but that it can be achieved through the cumulative efforts of ordinary men. Science itself grows, like a coral island, by slow accretion rather than some sudden upheaval. It has its Newtons and its Einsteins, but it trusts less to their brilliance and inspiration than to the capacity of an army of patient, often obscure, investigators to work together in groups. Its ideal is that of removing the hazards of chance from the growth of knowledge and the advance of human well-being. It is this idea of progress through cumulative effort, progress by coöperation, progress which does not wait for some brilliant stroke, some lucky discovery or the advent of some superman which may be rated as the chief contribution of science to social philosophy in these last two centuries.

To natural science with its ideal of cumulative and conserved progress, we may also credit the growth among men of an expectation of material abundance, with its involved train of political and social consequences. Primitive man with his instincts rooted in incessant struggles against cold, hunger, pestilence, enemies and stark want in every form, would have rejected the notion that mother earth could provide an abundance for billions of children as utterly fantastic. Like the old woman of the shoe she was overburdened with "so many children she didn't know what to do"—unless it was to kill off the surplus periodically. The ancients appear to have accepted aristocracy and slavery as ordained of nature; they were inescapable corollaries of scanty resources and meager production. Can we think it a mere coincidence that the growth of democratic ideals and institutions, of human hope in religion, and of social vision in ethics has come step by step with the advance of science and technology in these last two centuries? These ideals are the political, economic and spiritual affirmation of the credo of human progress, based on a possible abundance for man *in this world.*

How far removed we stand from the faith of the ancients that stoicism in the face of human misery and want is the highest of the virtues! How far apart, too, seem our Western world and the Orient of today. Charles A. Beard, the historian, testifies to his vivid impression on first coming face to face with the religions of India that these were the natural expression of the ideals of a people who have no hope of a square meal in this or any other world. If nature denies the possible satisfaction of the most elemental of all cravings, what greater boon can be sought than utter emancipation from all consciousness and desire?

Yet we in the Western world have our own adventures in fatalism, quite at the opposite pole to the passive fatalism of Asia. Think of the dazzled optimism of the Victorian era, when man's brilliant conquest of nature made the idea of progress seem as inevitable as the workings of gravitation. To set up any social control over discovery, invention and industrial exploitation was needless, in fact almost profane. "Hands off!"

proclaimed the prophets of *laissez-faire*—let natural law take its course and in time all would be well. Would that human welfare were so simple! The Great War demolished so naïve a social philosophy, as the last three decades have demolished the naïve natural philosophy on which it was based.

Fifty years ago chemists and physicists were confident that they had come upon the ultimate units of nature. These were atoms—minute, hard, indestructible, elastic billiard balls of stuff, controlled by the same universal law which held the planets in their courses. Where philosophers had once spun pictures of the universe out of filaments of pure thought, they now began to build themselves models out of the hard little atoms of the physicist and the chemist, with chance as the architect.

Was it not Thomas Huxley, the great expounder of mechanism in nature, who asserted that six monkeys, set to strum unintelligently on typewriters for untold millions of years, would be bound in time to produce all the books in the British Museum? In short, allow time enough and every conceivable accident was bound to happen. And here was man, whom Dante's world had dreamed of as the central figure in a drama of salvation on which all existence turned, reduced to a casual incident, just a chance grouping of minute billiard balls among millions of suns and plants whirling in inconceivable space.

Scarcely had the ordinary man begun to make himself at home in this mechanical cosmos when experimenters broke through the supposedly adamant foundation of the atom world into a stranger wonderland than Alice ever slipped into. Roentgen caught an accidental glimpse of it in 1895 and the Curies broke into it with more deliberate design in 1898. Here they found the hard stuff of matter dissolving into impalpable radiation, and energy—whatever that may be—turning itself into atoms and molecules. Here were transformations that seemed to defy prediction, anomalies which seemed to hint of some caprice in the chain of cause and effect. With a crash the entire solid, billiard-ball model of the cosmos collapsed. Is energy merely another aspect of blind matter? Is it something existing wholly apart from the realm of spirit? Scarcely a living physicist

could be found to assert such a dogma. How curious a day Huxley would find this, when certain biologists speak confidently of growing men to order in the laboratory if the need arises (note well that saving "if") and a school of psychologists proclaim faith in their ability to mold the new-born babe at will to any pattern of conditioned reflexes, and yet scarcely a physicist can be found who owns himself a thorough-going materialist.

And what shall we say of the overturn in our notions of time and space, of eternity and the infinite, of the ideal, the relative and the absolute? John Doe on the street may think of modern mathematics of four or forty dimensions as a fringe of insanity, but there is scarcely an idea in his head it has not revolutionized. The plain man has all but lost his sense of certainty, but has gained a great respect for probability. The only certainty he can count on is the certainty of continuing change. If you can not live adventurously, you are a mere onlooker in life's game. Max Planck, the Nobel laureate of a happier day in German science, says: "Science does not mean contemplative rest in the possession of sure knowledge." The man seeking contemplative rest, even on the vegetative level of intellectual existence, will have to go back to the 13th century for it.

Volumes could be written on the revolution in side-walk philosophy which has grown out of the biological concepts of organism and evolutionary development. John Doe's casual speech, without his being aware of it, is saturated with ideas based on genetic transmission, embryonic development, differentiation of structure and of function, modification by environment, the influence of survival values, and progress through successive stages of conception, gestation, infancy, maturity and final senescence. He not only applies these ideas to individuals; you may catch him any day applying them in a sweeping manner to communities, states, nations, races and whole civilizations.

Probably no aspect of behavior is more characteristically modern than that of specialization. Here the parenthood of science is clear and unmistakable. Specialization among the ancients was based primarily on skill. The oldest recorded craft appears to be that of the metal-worker. Before priest, law-giver, healer

or soldier was Tubal Cain, "the instructor of every artificer in brass or iron," only six generations after Adam. Specialization of function is also a venerable idea. Plato elaborated on it in his "Republic," a society composed of philosophers, producers and policemen; but no one can imagine Plato or Aristotle suggesting a society based on specialization of knowledge. Even as late as the 16th century, Francis Bacon who by profession was Lord Chancellor of England, was able to claim all knowledge as his sphere. The science of today, on the other hand, owes its fertility to specialists who keep breaking it up into smaller and smaller fragments in order to pursue it more intensively. Philosophy, in every age, has sought for unity of knowledge; science, for diversity. This antithesis has been made the theme of a structurally perfect epigram—that science is a means of learning more and more about less and less until one knows everything about nothing; while philosophy is a way of learning less and less about more and more until one knows nothing about everything.

The age of specialization leads inevitably to the age of the expert. The pioneer society of our fathers conceived its ideal man as a self-reliant, self-sufficient individualist. In the society which framed the Declaration of Independence and the Federal Constitution there was little to mark off one man from another except native intelligence, natural energy, the ownership of property and personal cultivation. Ten in eleven were living on the soil with all the highly localized interests of a rural society. Such men admire the versatile amateur and look with disfavor on the specialist, or suspect him of being a sharper bent on using his superior knowledge to do the common man out of his rights. The fathers, or at least those who followed Thomas Jefferson, had a profound faith in the collective wisdom of common men and distrusted the expert in government. Democracy was expected to transcend in some almost mystical way the limitations of the individuals who composed it. Alas, it seems to work the other way; we are dumber in droves and more inhuman in mobs than we are individually. The world of learning, the world of healing, the world of industry have learned to respect and use the expert and to thrive by it, while in government we soon tire of the

expert and kick him into the street, while the relieved electorate exclaims "Who wants to be run by a bunch of blanked experts? What we want is to be governed by folks like ourselves!"

We are, of course, still too close to the industrial revolution of the last 150 years to appraise it in any true perspective. The universal rise in the standard of material comfort is self-evident. What may be more important is the substitution for the fumbling process of trial and error the deliberate technique of progress as exemplified by the modern research laboratory. Alfred Whitehead in his "Science and the Modern World" reminds us that the most important invention of the 19th century was the invention of the method of invention. It is that, he asserts, which has broken up the foundations of the old civilization. Under its influence the world has lost its sense of ordered security. The inability of nations to compete in a technological society without abundant mineral resources has divided the world into the "haves" and the "have nots"—the one group seeking peace at any price and the other denying it on any terms until its wants have been met. The spectre which haunts both individuals and corporations is that of obsolescence, a word almost unused twenty years ago.

Industry makes economic life impersonal, while the total effect of scientific inquiry has been to heighten the individual's sense of insignificance. How far away and long ago sounds the song of the shepherd-psalmist:

> "When I consider thy heavens, the work of thy fingers, the moon and the stars, which thou hast ordained; what is man, that thou are mindful of him? Or the son of man, that thou visitest him? For thou hast made him a little lower than the angels, and crowned him with glory and honor."

When the astronomer of today has had his say, God may be the infinite mathematician; but man sees himself as a mere animated mite, lost in limitless space on a speck of cosmic dust. With this sense of individual insignificance has come a decline of interest in personal salvation and personal immortality. But as the concern to save one's own soul has lessened, the craving for social salvation and for a worthy share in the immortality of the life stream has grown apace.

In our search for spiritual security we cast aside every material circumstance and in nakedness of soul ask the universe if there is not something in man too valuable for it to abandon or destroy. What evidence is there that man serves a unique purpose in the economy of nature, that nature cares for him in a unique way or watches over him with loving solicitude? In all honesty, science can but answer "Of direct evidence, none whatever." There are, to be sure, certain inferences, certain sidelights of value. The conditions suitable for human life are rare in the known universe. Great time and pains have gone into man's making. Surely so intricate, so sensitive and so responsive a mechanism has value out of the ordinary. Man alone in the known order of nature fashions tools and instruments to overcome his own limitations. Man alone explores and seeks to fathom the mysteries of the universe around him. The senses which can discover and the intelligence which can perceive even fragments of the cosmic plan must be in some way akin to the all-enveloping intelligence they seek to fathom. Man is not merely an animated mite on a speck of cosmic dust; he is the astronomer who from things merely seen, heard, felt, smelled or tasted dares in his imagination to frame a picture of the universe. And so with groping fingers we touch the hem of the garment of eternal reality.

To the soul in search of spiritual security amid hostile forces, these intimations are far from satisfying—no clear trace of a cosmic father who loves and cares as well as a cosmic architect who plans and builds, no clear trace of spiritual sonship, no clear trace of indispensable purpose for man as race or individual, no clear trace of unique significance in life; just a touch of a hem of a garment.

On the issues of existence, science remains largely neutral. It offers facts, but man can not live by facts alone. The human spirit craves not facts, but truth. Truth is to facts as a house is to the bricks which compose it; bricks plus design, proportion, beauty, unity and worth. The world of sight, which belongs to science, does not exclude the world of insight, which belongs to religion.

It is not only a happy circumstance, but a fact of deep signifi-

cance, that science has flourished so fruitfully these last fifty years in this institution calling itself "a Christian college of liberal arts." Over much of the world of today the liberal spirit suffers violence. In the dark years before the re-birth of learning in Europe the monasteries rendered an unforgettable service to civilization by keeping the lamp of knowledge alight. In our day the preservation of the liberal spirit in the college and university may prove to be a service of equal significance. So long as the company of scholars unites in good will and generous collaboration—the scientist, seeking to sift fact from falsehood; the humanist, seeking the golden mean between extremes of folly; and the man of religion, striving to bridge the gap between common sense and saving wisdom through spiritual insight—the liberal spirit will endure!

THE APPLICATION OF PHYSICS TO MODERN HYDROGRAPHIC SURVEYING

HERBERT GROVE DORSEY (D. U., '97)*

Address given at a Symposium on Science and Human Welfare, held at Denison University, June 12, 1937, in Commemoration of the Semi-centennial of the Founding of the Denison Scientific Association.

INTRODUCTION

Few people realize the value of nautical charts unless they have been rather closely associated with their actual use. Nearly everybody is familiar with road maps so it might help in understanding a nautical chart to note that it gives three dimensions instead of the two we usually find on the road map. If the latter would tell the depth of the mud or of snow, in the winter, it might be comparable with the chart, which gives the positions of land, lighthouses, buoys, etc., but also the depth of the water, so that the navigator may know if it will be safe to pilot his ship along certain courses and channels.

The commerce of the world is carried on largely by shipping, and in a single year cargoes passing to and from New York alone may be transported by as many as 5,000 ships having a registered tonnage upwards of 23,000,000 tons. While the port of New York is the largest in the world, having a combined value of imports and exports approaching four billion dollars annually, there are hundreds of other ports busy all the time with incoming and outgoing ships. This traffic is all dependent on one method of guidance—the nautical chart. Remove all charts with their information and shipping would be at a standstill; unless some method was at hand for visually positioning the modern networks of buoys, radio beacons and other aids to navigation, conditions would become chaotic, reverting to pioneer days when there were no charts.

* Principal Electrical Engineer, U. S. Coast and Geodetic Survey.

CHART MAKING

In making a chart there must be known: first, the shore line, showing the relation of prominent objects and points of land with reference to the rest of the earth's surface; second, the position of the survey ship with references to the shore line; and third, the depth of the water.

The shore line is established by the surveying necessary for correlating the region to the general triangulation network of the United States. Prominent objects, such as church steeples, towers, etc., are located to known positions by theodolite angles and by plane table surveying. Where necessary, along barren coasts, shore signals are built and their positions determined. The surveying ship makes a "boat sheet" of heavy, cloth backed, drawing paper carefully ruled with a polyconic projection of the latitude and longitude of the area to be surveyed, and on which are marked the locations of prominent objects which may be seen from the ship. When the ship's position is desired, two sextant angles are simultaneously taken on three shore objects, and are then set on a three-arm protractor, which instrument is then moved around on the sheet until the three arms coincide with the three objects, thus locating the point that was the ship's position at the instant the angles were taken. Meanwhile the ship is steaming ahead, taking soundings at regular intervals and following an orderly system of lines, usually parallel to the shore, or at 45° to a valley, if the area is known to include one. The course of the ship is continuously plotted, and, if the lines are not straight (due to wind or currents), the helm is changed at each position so as to keep as straight a line as possible. At the end of the line the ship steams over a distance where it starts another line back parallel to the first, usually continuing this procedure throughout the day from dawn to dark. Soundings are taken at regular intervals varying from 15 second spacings for depths of 2 fathoms to periods of 1 minute between measurements in several hundred fathoms, while the ship's position is obtained from every 3 to 5 minutes up to 15 or 20 minutes, depending upon the depth and ease of holding the course.

The soundings are recorded in a book, along with all other

data about position, course, etc. They are also plotted on the boat sheet as the work progresses, and, in addition, rough contour lines are drawn so as to give a general idea of the nature of the bottom. If any unusual area appears, such as a shoal or a valley, detailed development work is planned so that a more comprehensive survey may be made of the region while the ship is near the locality.

RADIO ACOUSTIC RANGING

The aforesaid method of hydrographic surveying is continued seaward until the shore signals can no longer be seen. Along mountainous coasts this may be as far as 75 miles, but for the eastern United States and the Gulf of Mexico it is seldom more than 10 or 12 miles. Beyond this distance the ship's position is located through the use of a method developed by the United States Coast and Geodetic Survey about 1923 and used with increasing improvements and success since that time. It is called *Radio Acoustic Ranging*, as it involves subaqueous acoustics and radio signals (Plate I). The name of the method is abbreviated to RAR and is known by those letters throughout the bureau. Whenever the ship's position is desired, and recourse to modern RAR methods is necessary, a small bomb is dropped overboard. It explodes in the water and the time of its explosion is recorded on a chronograph tape. The sound is then propagated through the water to two or more different hydrophone stations, which may be from 10 to 40 miles apart, but the positions of which are accurately known and plotted on the boat sheet. The sound received in the hydrophones (Plate II, Fig. 1) is amplified to such an extent that it automatically transmits a radio signal back to the surveying ship from each hydrophone station. These radio signals actuate the chronograph on the ship, so that the bomb record is followed by each of the radio signal records on the tape. Another pen records second intervals on the same tape from a break-circuit chronometer so that the time intervals from the firing of the bomb to the return of the radio signals can be measured to hundredths of a second (Plate

II, Fig. 2). Knowing the velocity of sound in water, the distances can be calculated, and the ship's position readily computed. Instead of calculating the distance, however, it is scaled from a special steel scale graduated in distances for time intervals. A beam compass is set to the proper time interval on the scale, and a small arc is described on the boat sheet from the plotted position of the hydrophone station. This is done for each one of the hydrophones, and it is not uncommon to have the arcs from four separate stations intersecting in a point even for hydrophone distances of 5, 15, 20 and 35 miles from the ship. Such concurrences indicate that the velocity of sound is uniform in the different directions, that the hydrophone positions are accurately known, and all the intricate apparatus at five different locations is properly functioning.

VELOCITY OF SOUND IN WATER

Who has not observed the nearness of a storm when the interval between the flash of lightning and the accompanying thunder is short! Doubtless a large percentage of people actually guess at the distance of a storm by this time interval, even if they do not get the more approximate distance by "counting to five" for each mile. And many are those who have been astonished at the loudness of sounds in water, when they held their ears under while bathing. But it is doubtful if many have realized the far greater velocity of sound in water over its rate of travel in air. The magnitude of the increase is about four and a half times, and results in a speed of 4,920 feet per second in sea water, plus or minus a small quantity according to the variations in temperature, salinity, and pressure. Fortunately for modern hydrographic surveying and the applications of physics thereto, the variations in the velocity of under-water sounds are not large, since the fluctuations ordinarily encountered are not so much as five per cent. In general these deviations permit accurate corrections, for the different variables are well known, and RAR methods usually are so accurate that the total error is only from about one part in 600 to 1 part in 1,000.

DIFFERENCE BETWEEN ATLANTIC AND PACIFIC

RAR was first used on the Pacific coast, and, except for the usual difficulties attending any new venture, it was successful from the beginning. Had it been tried first on the Atlantic coast, so many difficulties would have been encountered that the attempts would probably have been abandoned. The Pacific Ocean deepens rapidly, while the Atlantic depth increases slowly. The first is a hundred fathoms deep (600 feet) a few miles from shore, while on the east coast one must go possibly 50 miles to reach a hundred fathoms. It is now well known that sound is not so readily transmitted through shallow water as through deep, but that was entirely unknown in 1926, two years after RAR was in successful operation on the west coast. Trials were made off the North Carolina coast, and, in water depths of 5 to 15 fathoms, bombs of TNT a quart in size would not operate the apparatus more than 10 or 15 miles distant; whereas similar bombs in the Pacific, in water from 10 fathoms to 1,000 fathoms in depth, had been successful for more than 100 miles.

The method used on the west coast is to have a cable extend from the shore to a point past the outer line of breakers, terminating in a hydrophone mounted on a stand supported about three feet from the bottom on a concrete base. The hydrophone may be thought of as a waterproof microphone, similar to those used in a broadcast studio, and is the instrument through which the sound waves in the water are transferred to the cable and thence to shore. There a small radio house is built, where a radio operator lives for a month or two with the necessary amplifier and radio transmitter for returning the bomb signal to the ship. This hydrophone station is occupied only so long as is necessary to do the surveying in that region, whereupon the entire apparatus is moved to another locality. The radio operator is in communication with the surveying ship at regular intervals, and is always standing by when bombs are being fired so that he may monitor the reception of the bomb signals in the hydrophone and the sending of the radio signal. In the early days of RAR several relays were involved in the operations, but,

as the art advanced, relays have been eliminated entirely in sending the signals; the work is now done by electronic tubes. Thus any variable lag due to mechanical inertia and friction has been replaced by the nearly instantaneous action of thermionic tubes.

FLOATING HYDROPHONE STATIONS

Since shallow water near land on the Atlantic coast prevented use of the standard methods of shore stations, the only alternative was either to run cables 5 to 8 miles long from the shore to deeper water or use ships from which to hang the hydrophones. Long cables are impracticable for temporary usage, but a preliminary test indicated that with ships anchored in 10 fathoms or more RAR could be successfully used on the Atlantic coast, and would be far more accurate than any method of so-called "precise dead reckoning" where the ship gets its position from shore and then runs seaward and obtains its position from course and distance run and star fixes, and then moves over to run another line inshore and take another position, adjusting any drift which may have occurred due to wind or water currents.

The entire area of Georges Bank, east of Cape Cod, was successfully surveyed in the three summers of 1930, 1931 and 1932. This was accomplished by starting 180 miles east of Cape Cod and working back to shore where the closure was less than a quarter mile, testifying to the good quality of this method of surveying where all the work was beyond sight of land except the very last part.

While the method continued to be used with good results along the coast east of Maryland and south of Long Island, it became evident that it was very expensive to keep a ship anchored for the sole purpose of using it as a hydrophone station. Launches were used successfully, but then the apprehension of a small launch being 70 miles or more from shore if a storm should come up suddenly with the possible danger of loss of life enforced the necessity of having something to replace the launches. So there was developed the sono radio buoy (Plate III).

SONO RADIO BUOY

This has proved very useful, and while it has not entirely replaced launches it is in a fair way to do so. The advantage may outweigh the disadvantages completely. The launches can use greater power on their radio signals and thus give better returns when there is much static. The radio operator on the launch can increase his audio amplification just before the bomb signal is received and can also identify the bomb sound from other noises and tell the surveying ship which was the correct radio dash sent, when several may be sent in succession. But these are about the only advantages of the launches.

The Sono Radio Buoy or SRB, as it is called, can do only the operations for which it is designed and no others. If a ship is passing, it will send out radio signals caused by the ship's noise operating the hydrophone. The strength of its radio signal is limited, so that if static is heavy the SRB cannot be used to such a great distance as when there is comparative quiet. The advantages of the SRB are many. At least two station ships or two SRBs would be required and a comparison of expense is very enlightening. Two SRBs cost only about $400 and the upkeep is about $1.00 per day, while two launches cost about $110,000 and the expense of operation, including personnel, is about $180 per working day. The launches cannot anchor safely in water deeper than about 30 fathoms while the SRBs can be anchored in 60 fathoms. This is a very great advantage because it brings the hydrophones 15 to 20 miles closer to the deep water of the ocean, so that the surveying ship can proceed out 50 to 75 miles beyond the SRBs to where the water may be 1,000 or 2,000 fathoms deep and still determine her correct position by RAR methods. The SRBs can remain on station for as much as 50 days without any attention to tubes or batteries, ready at any time, day or night, to respond to bomb signals. Only one has been lost in two seasons, due to a hurricane in the Gulf of Mexico.

Surveying buoys for floating signals had been used for many years and it was natural to utilize what already had been developed successfully. Such a floating signal consists of an empty

55 gallon oil drum enclosed by an open wooden framework of 2 x 4 inch lumber above and below the drum so that the superstructure projects about 15 feet above water. A counterweight is attached to the lower end of the framework to keep it upright and an anchor keeps the buoy in position wherever desired.

For the SRB an additional drum is used having the upper end modified so that it can be opened to insert the electrical apparatus and then closed water tight. The second drum is placed above the first, making the SRB long and slender, with high stability in a seaway. The apparatus is built as compactly as possible and comprises a three stage amplifier, a keying tube and a transmitting tube. All tubes are the 2-volt filament type and are all biased to cut off, so that no plate current flows except when a sound signal is received. The filaments are heated all the time the SRB is on station, a small hand hole at the top permitting the battery switches to be closed, sensitivity adjusted and final tuning made just before the SRB is put overboard by the surveying ship. Dry batteries are used entirely for A, B and C voltages. The B and C batteries will last a whole season of six months, and the A batteries and tubes about three months. The batteries are placed in a light wooden crate in the lower part of the top drum. A hydrophone of the electrodynamic type is suspended about 40 feet below the water surface, its cable passing through a stuffing box in the top plate. The amplifier uses two 32-tubes and one 30-, the total gain being about 95 decibels. This is sufficient to operate the transmitter if one strokes the face of the hydrophone as gently as possible. If the hydrophone is placed in a bucket of water and a single small shot is dropped into the water from a height of a foot, it will actuate the transmitting tube. A ship passing within a mile or so will actuate the SRB by the noise from the propeller. Greater amplification is useless because it then becomes so sensitive that the lapping of waves on the oil drum or the timbers is sufficient to cause the emission of radio signals almost continuously and it could be used only on perfectly calm days.

The amplified signal passes to a second 30-tube which is in-

verted, electrically, its filament battery being separate from the other, and connected to the screen grid of a 33-tube. The latter, being the transmitting tube, has its grid negative, by 16.5 volts, just sufficient to keep it from oscillating when it has no positive potential on its screen. The grid circuit also contains a quartz crystal, clamped, with low temperature coefficient. When the second 30-tube is actuated, electrons are drawn through its filament from the screen of the 33-tube, producing sufficient positive charge on the screen so that the 33-tube oscillates at the frequency of the crystal for about one-tenth second, or longer, if the sound of the bomb comes in as a rumble, as it does if the bomb is 20 miles or more away—the rumble being caused by reflections of sound, or echoes, just as when thunder is heard at a distance. The minimum time of one-tenth second is caused by a one microfarad condenser between ground and screen of the 33- which serves both as a screen blocking condenser and signal sustaining condenser. Since it must be charged by the screen positive charge before the 33- oscillates, there is a slight delay in the starting of the signal by about 0.006 second. A larger condenser will give longer radio signals, but then there is also more delay in starting the signal and the delay is not constant but varies inversely as the strength of the bomb signal. Laboratory and field experiments show that one microfarad is a satisfactory value and one-tenth second adequate to make a good mark on the chronograph and permit an operator, by the pitch of the note heard, to identify which SRB is giving the record.

Each surveying ship has its own radio frequency for RAR work. Crystals for this group are ground to the same frequency within about 10 cycles, which is sufficiently close, as the timing condenser may make 50 to 100 cycles difference in the emitted signal. Two ships working in the same vicinity do not interfere with each other as one will have the frequency of 4160 kilocycles and the other, 4135 kilocycles. In another locality one will have 2492, a second 2496, and a third 2500 kilocycles. For any particular ship the SRB frequencies will be such that the radio signals will come in as two or three separate whistles of slightly different pitches. Since all the SRBs are in water of

nearly the same temperature, the frequencies of all may rise or fall slightly with the temperature of the water, but once put on station the frequencies remain constant except for this slight temperature effect. The power output of the 33-tube as a transmitter, with 180 volts on its plate circuit, is about 6 watts, which gives a signal which has been recorded on the chronograph at 75 nautical miles. The useful range of the SRB varies with the depth of the water, being from about 15 nautical miles when anchored in 10 fathoms to 50 or more miles when anchored in 50 fathoms. The ultimate distance in the latter case has not been determined, as the greatest distance tried at present writing is 60 nautical miles on a quart TNT bomb. The ranges for the station ships are of about the same order.

HISTORY OF DEPTH MEASUREMENT

Having learned how to locate the position of the ship with reference to shore it is next necessary to measure the depth of the water. This art is probably "as old as the hills." In the dim past, before the dawn of any form of civilization as we now think of it, man probably rode astride a floating log long before he hollowed it out to form some kind of a canoe. In either case he would use a pole to push himself along, and this pole would also serve as a measure of depth, a method still in use. Later, he used a string and stone, and the line and lead weight method was probably very ancient even when Herodotus, the Historian, in Book II, 5, recorded 450 years B. C. about the journey to Egypt, "When you are still approaching in a ship and are distant a day's run from the land if you let down a sounding line you will bring up mud and you will find yourself in 11 fathoms." They probably used grease on the bottom of the lead then, just as is done now, to get a sample of the bottom. In describing the Apostle Paul's stormy voyage on the Mediterranean sounding is mentioned in Chapter 27 of The Acts of the Apostles: "... About midnight the shipmen deemed that they drew near to some country; and sounded, and found it twenty fathoms: and when they had gone a little further, they sounded again, and found it fifteen fathoms."

The lead and line are thus known to have remained standard for at least 25 centuries, and no real improvements were made until the latter half of the 19th century. Improvements had been tried and it was well known that they were needed. Some 200 years ago navigators were learning that there was some sort of a continental "shelf" at a depth of about 100 fathoms, beyond which the depth increased rapidly and was very difficult to measure. This was where the blue waters of the ocean began and it was realized that if some easier way of measuring the depth were discovered, it would be a great aid to navigation.

Among the direct methods used for obtaining greater depths was that of dropping a cannon ball attached to one end of a roll of small cord of known length. When the cannon ball reached the bottom, as was indicated by the sudden decreased rate of paying out of the cord, it was cut and the length remaining in the roll was measured, the difference between the original length and the remainder, giving the depth. Next came the method of attaching the weight to a long rope which, after the depth was measured, was pulled aboard by hand. The great difficulty was to tell the exact instant that the weight struck the bottom. The Annual Report of the U. S. Coast and Geodetic Survey for 1846 commented on the difficulty of using hempen line and stated that 2.5 hours were required to haul it in after a sounding of 2,160 fathoms. In a personal letter, the Commanding Officer wrote that it required 30 men, "including the Cook and Waiters," to haul in the line.

A vivid illustration of the inability to tell when the weight reaches bottom with a hempen rope was given when the British Warship HERALD, Captain Denham, obtained a sounding of 7,660 fathoms in latitude 36° 49′ south, longitude 37° 6′ west. Recent soundings have shown that the actual depth at this position is only 2,734 fathoms.

Steel piano wire was tried with indifferent success until Lord Kelvin's wire sounding machine was developed in 1872. Since that time wire has been used exclusively in the U. S. Coast and Geodetic Survey as it is both more accurate and easier to tell when the weight strikes bottom. Steam and electrically driven

sounding machines, with piano wire to carry the weight, are still the standards for checking other methods and for obtaining temperatures and bottom samples. A comparatively small drum will hold 3,000 fathoms of piano wire and for horizontal measurements a length of 140 miles is carried on a larger roll.

INDIRECT METHODS OF SOUNDING

Of the indirect methods of sounding, one may mention that of Ericsson, who, in 1837, used the compression of air to cause water to flow from one tube into another. By applying Boyle's Law the pressure could be computed, and therefrom the depth. This tube apparatus had to be lowered and raised vertically, a difficult procedure. Although others tried to improve the method, it was not until 1881 that Lord Kelvin made an instrument in which the tube need not be kept vertical. This method was still further improved in accuracy and speed in 1911 by Captain G. T. Rude, now Chief of the Division of Hydrography and Topography of the U. S. Coast and Geodetic Survey.

Another indirect method was that of Siemens, who in the middle of the last century balanced a column of mercury against a spring and obtained a continuous indication of depth by the change in gravity over different parts of the ocean, the pull of gravity being less where the water is deeper. Although ideal in principle, the method is not suited to ships and is also affected by the change in gravity due to variations in latitude.

ECHO SOUNDING

While actual measurement of ocean depths by echoes has become practical only in recent years, it appears to have been suggested as early as 1807 by the noted Parisian astronomer and physicist, Arago. Experiments were actually tried in 1855, when Maury fired gunpowder in the water and listened for the echo which he was unable to hear. We now know that the experiment would have been successful had suitable hydrophones been available with which to listen for the echo.

The sinking of the Titanic by collision with an iceberg in 1912 set many persons thinking of how icebergs might be detected in

time to avoid an accident. Records show that at least two believed it might be possible to get under-water echoes from icebergs by sound waves.

Dr. Alexander Behm, an Austro-German physicist, began experimenting by photographing sound waves in a small aquarium, and from the photographs concluded that sounds in water would actually produce echoes. He next photographed echoes in Heikendorf Bay, near Kiel, and was thus probably the first actually to get records of echoes from the bottom. The process was too complicated, however, to be of any commercial service.

Professor Reginald A. Fessenden, of Boston, had previously developed a very powerful signalling device for under-water work and devised a timing machine whereby he could listen for the echo in a telephone on one car and to an artificially produced echo in a telephone on the other ear. By rotating some contacts by means of a hand-wheel until these two sounds were heard simultaneously, a pointer on the hand-wheel indicated the distance from the reflecting surface.

With this indicating device and his submarine oscillator for producing the sounds Fessenden first received echoes from the bottom of the ocean and later from icebergs. Thus, Fessenden was probably the first actually to produce a machine for measuring depths. However, it involved the necessity of matching two sounds with head phones and required some skill in getting depths; furthermore it was impossible to measure less than 80 fathoms and consequently did not cover the low range in which navigators are primarily interested, so Fessenden's device was not marketed.

THE FATHOMETER

With this model as a beginning, the Submarine Signal Company of Boston, developed the fathometer, pronounced Fath-o-meter, as a practical navigational instrument, while the writer was one of its engineers. The depth is indicated in fathoms on a dial by a flash of light and is as easily read as a clock.

The fathometer (Plates IV and V) consists of 4 parts: a sound producer to send out the signal, bolted to the bottom of the ship;

a sound receiver to pick up the echo, in a tank of water bolted to the inside of the steel hull of the ship; a thermionic amplifier to increase the volume of the weak echo received from the bottom of the ocean; and an indicator to show the depth.

The sound producer, called an oscillator, may be likened to a powerful telephone receiver, made water-proof. The diaphragm, about 13 inches in diameter, has a group of steel laminations welded to its center, inside. A corresponding group of laminations is welded to a rear thicker housing, and a small coil of wire around them carries an alternating current of 525 cycles whenever the circuit is closed at the indicator. The diaphragm is tuned to a natural frequency of 1050 cycles per second in water, and by a pull every half-cycle of the 525 cycle current, the frequency of the diaphragm is double that of the sending current. The efficiency is such that it requires only 500 watts excitation for depths as great as 3400 fathoms. The alternating current is supplied by a small converter operated by direct current from the ship's supply.

HYDROPHONES

The hydrophones are similar to the carbon-button microphones used in telephone transmitters, built into a water-proof case. These cases are rubber for shoal depths, and brass, with a tuned diaphragm, for greater depths. The diaphragm, being tuned to the same frequency as the oscillator, makes a more sensitive combination. In any hydrophone used in sub-aqueous work it is necessary to employ what is called an inertia type, where one side of the carbon button is fastened to the diaphragm and the other side is left free. This is necessary to prevent different pressures, due to different amounts of submergence, from squeezing the carbon granules so tightly that they will not vibrate when a sound wave is received. By moving the front part of the button a slightly greater amount than the rear part, the carbon granules are agitated and so change the resistance.

AMPLIFIER

The amplifier is a thermionic tube affair of two triodes in series with a lamp resistor and choke connected to the ship's 110 volt

D. C. circuit. Current for the microphone is supplied by dry cells, but the amplifier is operated without batteries. This circuit is extremely simple and gives sufficient amplification to operate a thyratron, in the plate circuit of which is a charged condenser and primary of a transformer. When the echo is received the grid of the thyratron is changed from negative to positive and the plate condenser discharges to produce a high voltage which makes a flash in a neon tube rotating inside the indicator.

INDICATOR

The indicator is generally located in the pilot house of the ship so that the mariner may see the depth at any time. It consists of a casing bolted to a bulkhead and contains a small motor with a governor to run at a constant speed. A vibratory tachometer is included to show if the speed is correct, and a small rheostat enables one to adjust the speed if it varies, due to fluctuation of the ship's voltage. This motor is geared to a disc, turning approximately four times per second, on a horizontal axis. Mounted on the back of the disc is the small neon tube already mentioned, and a slot through the disc allows the flash of light from the neon tube to be seen through a graduated glass dial mounted immediately in front of the rotating disc. This dial has one scale graduated from 5 to 100 fathoms and another scale graduated from zero to 600 fathoms; a shift in gears rotates the disc only 40 times per minute when the second scale is used for measuring great depths.

When the neon tube passes the zero of the scale electric contacts close the circuit for a brief interval between the converter and the oscillator, sending a signal. While the sound is traveling to the bottom and back as an echo, the disc has been rotating at its constant speed by an amount proportional to the depth, acting to measure the time interval elapsed between the time the signal was emitted and when it is received. The flash in the neon tube then indicates the depth and as this is repeated at regular intervals soundings may be taken at any time, day or night, with the ship going at full speed.

Such has been the fathometer as used by the Coast and Geodetic Survey for obtaining depths for making charts from 1926 to 1935. With various modifications in different models as a commercial instrument, it has been installed on some 800 commercial and naval ships. It is not a precision instrument and was never intended to be more accurate than is necessary for navigation. The ideal of the Coast and Geodetic Survey, however, has always been to make charts which are accurate and it was realized that as more and more fathometers came into use some ships might get soundings which differed slightly from those shown on the chart and thus cast doubt on their value. Furthermore, the percentage of error of the fathometer increases in the shoal depths, the very range where it should be more accurate. Consequently it was decided by the Coast and Geodetic Survey to develop a precision instrument which is now called The Dorsey Fathometer (Plates VI–IX incl.).

THE DORSEY FATHOMETER

Since the fathometer is primarily a time-measuring device, its speed, if it is to be an instrument of precision, must be more constant than can be maintained by any ordinary governor. Consequently it was decided to run a synchronous motor from a tuning fork. As contact points wear and change their adjustment the signals are sent by flashes of light to a photo-electric tube. Contacts on slip rings cause variable friction so that instead of rotating the neon tube which gives the indication an annular neon tube is used. Thus there are no moving contacts of any sort and nothing to wear out except the ball bearings.

As the critical range is below 20 fathoms, the value of the scale is zero to 20 fathoms and since with more echoes there is less chance of having errors, it was decided to have about 20 soundings per second.

When the sound is produced on one instrument and the echo received on another the scale must be slightly altered in the shoal range, since the sound must travel farther than twice the actual depth. It was therefore decided to send and receive on the same instrument so that the scale could be graduated uniformly.

One more refinement was considered essential; to use sounds of high frequency so that several cycles of the driving current would be completed during the brief time the signal is sent.

These ideas were all combined in an apparatus which has been spoken of by the commanding officer of one surveying vessel as "the last word in sounding machines." The four principal elements are, first, the transceiver for sending the signal and receiving the echo, bolted to the bottom of the ship; second, the power supply, to operate the transceiver and indicator motor located in any convenient dry position; third, the amplifier to increase the strength of the echo; and fourth, the indicator.

TRANSCEIVER

The transceiver consists of a circular steel housing about 15 inches in diameter containing nickel tubes against which is pressed a steel diaphragm. When the nickel tubes are magnetized they change length by a process called magnetostriction and it is this change in length which vibrates the diaphragm. Conversely, if the diaphragm is vibrated by the echo, the change in length of the tubes generates a small e.m.f. in the wire coils surrounding them and is passed on to the amplifier. Since this part of the apparatus must both transmit the signal and receive the echo it is called a transceiver. The signal, at a frequency of about 17,000 cycles per second, does not spread in all directions like the lower frequency signals do, but is confined to a conical beam of about 30 degrees. For this reason the transceiver must be placed with its diaphragm in a horizontal plane, when the ship is on an even keel. If the hull of the ship is not flat at this location a fairwater is built around it so that there will not be ripples in the water nor air bubbles which act as a blanket through which sound cannot pass.

The Coast and Geodetic Survey ships are all equipped with 110 volt direct current generators. From this source a one kilowatt converter changes d.c. to 110 volt 60 cycle current which is next raised in voltage by transformers, rectified and filtered. One portion is for the 17.5 k.c. transceiver, another for a 1025 cycle tuning fork and a synchronous motor in the indicator and

another portion used for the keying circuit. All this is built into a well ventilated cabinet.

The amplifier is a 10-tube superhetrodyne in which the 17.5 k.c. echo is transformed to 175 k.c. and amplified to such strength that it actuates the neon tube in the indicator; the total gain available being about 150 decibels. The amplifier should be placed near the indicator so that adjustments may be made while watching the indication. A very severe condition exists because the amplifier, being connected directly to the transceiver, receives the sending signal of about 400 volts and immediately afterwards the few microvolts of the echo must be amplified. However, the entire circuit recovers in about three thousandths of a second so that depths of 9 feet under the transceiver have been measured.

The indicator includes a synchronous motor and a small auxiliary motor to bring it to speed. The rotor consists of a wheel with 100 slots mounted on a shaft supported in ball bearings. Mercury is carried in an annular channel in the wheel to help keep the speed constant. On the shaft there is a small concave mirror and at the outer end of the shaft is a thin aluminum disc having a single pointed slot. Mounted back of this disc is a neon tube bent into a circle 7 inches in diameter. In front of the disc is a glass scale graduated from zero to 20 fathoms, and subdivided into feet. If straightened out the scale would be about 25 inches long and a graduation of one foot is slightly more than 0.2 inch in length.

At the top of the indicator an automobile 6-volt headlight bulb is mounted in a small housing so that its light shines into the indicator and is reflected by the mirror, once each revolution, back through an adjustable slot to a photoelectric tube, type 918, set in another small housing mounted on top.

The standard velocity of sound adopted by the Coast and Geodetic Survey for calibrating fathometers, is 820 fathoms per second, and to make the readings correct for this velocity with a scale of 20 fathoms it works out conveniently to have a speed of 20.5 revolutions per second, attained by running the 100 toothed rotor with alternating current of 1025 cycles per second.

A tuning fork of steel having low temperature coefficient of the modulus of elasticity is driven by thermionic tubes and a portion of this current is amplified to about 100 watts and applied to the stators of the synchronous motor. When the rotor is brought to the right speed and phase it will run at the correct speed of 20.5 revolutions per second. It either runs at correct speed or not at all.

In order to be sure that the frequency of the fork, and consequently the speed of the indicator motor have the correct values, calibration signals at the rate of 20.5 per second are sent to the ships by radio, at prearranged times. These signals are timed by a piezo electric crystal oscillator and multivibrator circuit and are received on the ships in the regular manner and applied to the amplifier so that 41 flashes are made on the dial every 2 seconds. This is one flash per revolution, and if the indicator is running at the correct speed the flash of light will remain stationary at the same place on the dial, but if the speed is incorrect the flash will slowly rotate clockwise if the speed is too high and counterclockwise if too low. By this method the indications of depth are held so nearly correct that the error is less than one part in ten thousand or $\frac{1}{8}$ inch in a depth of 104 feet—an amount far less than could be discovered in depth measurements.

OPERATION

At each revolution of the indicator shaft the mirror reflects a beam of light on to the photo tube producing a short pulse of electricity which is amplified until a pair of tubes in push-pull circuit have their grid bias changed to a value where they oscillate a short while at 17.5 kilocycles per second. This alternating current is amplified and passed on to the transceiver which sends the pulsations into the water, receives the echo, and the amplifier causes a single brief flash in the neon tube. This flash is so quick, lasting only one or two millionths of a second, that, when shining through the slot in the disc, causes the latter to appear as though standing still. The echoes return so often, 20.5 times per second, that the depth appears as a continual line of light. A flash is produced when the signal is sent and this

flash is so steady that no variation can be seen for hours at a time; and when the ship is passing over a smooth bottom and there is no swell the echo flash is almost as constant. A change in depth as small as 2 inches can be detected. If there is a swell on the ocean it will be shown on the indicator and the flash of light will swing back and forth like a pendulum as the ship rises and falls on the swell.

Depth measurements are so accurate and consistent that cross line soundings, made to check results, seldom differ by so much as a foot in uniform and smooth bottom, results better than were formerly obtained by hand lead soundings taken at slow speed.

MEASURING TIDES AT SEA

Besides indicating the swell of the waves the change of depth with tide is easily observed while tied to a dock. Just recently a good 12 hour tide curve was obtained in the Gulf of Mexico, 27 miles from shore. The ship was anchored in 12 fathoms over a smooth bottom and the swell was only one foot. The fathometer was kept running all night and readings made every half hour. After averaging, to eliminate the swell, no reading was in error by as much as one-tenth foot. These points plotted as a regular smooth tide curve, the variations probably being less than would be had by readings from the tide staff. From these results it is probable that tide observations at sea will become a regular part of the hydrographic surveying. It is evident that the corrections which are made to soundings for height of tide will be more accurate if the tidal curves are made right at the area surveyed than from tide records made at the shore several miles away.

DORSEY FATHOMETER NO. 2

The fathometer just described has proved so valuable for the range from 2 to 20 fathoms that a second model (Plate IX) has been developed based on the same principles for accuracy. The only difference is that it runs at a slower speed so as to encompass a greater range in depth and fewer soundings are obtained. One scale is graduated from zero to 100 fathoms and gives 246 echoes

per minute while a second scale from zero to 1000 fathoms gives only 24.6 echoes per minute. One neon tube serves for both scales, the light shining through a slot in a disc for the outer 0 to 100 scale while a prism rotating on an arm reflects light from the tube to the inner scale.

The signals are sent by letting light shine through a slot in a rotating disc to a photo tube. There are two photo tubes and two rotating discs, one for fast and the other for slow speed, the two shafts being mounted concentrically. To change from fast to slow keying it is only necessary to switch from one photo tube to the other, one source of illumination serving for both.

The application of physics to hydrographic surveying has just about doubled the speed of operations. The unit cost of gathering data has been about halved, which means with a given amount of money approximately twice the amount of work can be done. Furthermore, the work is not only done faster but with greatly increased accuracy. These improvements have been made within the last 14 years and much of the work done now, with detailed surveys far offshore could not have been done 15 years ago. Soundings were so few and far apart that no accurate contours could be drawn. Now gorges on Georges Bank and the canyons of the prehistoric Hudson and Delaware Rivers are so depicted that even geologists are getting very much interested in how the floor of the ocean appeared when it was land and not an ocean.

Fishermen are equipped with fathometers and study the charts to seek new feeding grounds for they have found how to locate such areas with fathometers, and thus increase their catch.

The value of a good chart to the navigator with an echo sounding machine is very great. Any considerable sudden difference in depth serves as a land mark, whether it be a hill or valley. It is as permanent as the "eternal hills" and probably more so. No storm will make it drag anchor as a light ship may nor can the roughest sea extinguish its light. If it is in the regular course of ships it constitutes a marker for the modern navigator more permanent than any lighthouse.

The valleys discovered on Georges Bank (Plate X) are already telling the west bound ships from Europe their position 6 to 10 hours before they reach Nantucket lightship. This knowledge may mean thousands of dollars to the ship owners. Doubtless as offshore surveys are accurately completed deep sea valleys will become more and more useful for navigation. There are few places on the coastal waters of the United States where the depth remains really constant over any considerable area. If a ship navigator utterly lost in a fog should steam along slowly and plot the depths for 15 or 20 minutes on transparent paper, and then move this paper over an accurate chart until the depths agreed approximately with the chart, he would know his position in most cases.

As work with the fathometer progresses it is learned that the bottom of the oceans, if the waters were drained away, in many regions would look not very different from the contours of the earth's surface to which we are accustomed; hills, dales, valleys, mountains and mud flats. While highly improbable, it is conceivable that present day nautical charts may serve as fairly good topographical maps of portions of the ocean some millions of years hence.

PLATE I

SCHEMATIC REPRESENTATION OF HYDROGRAPHIC SURVEYING WITH STATION SHIPS

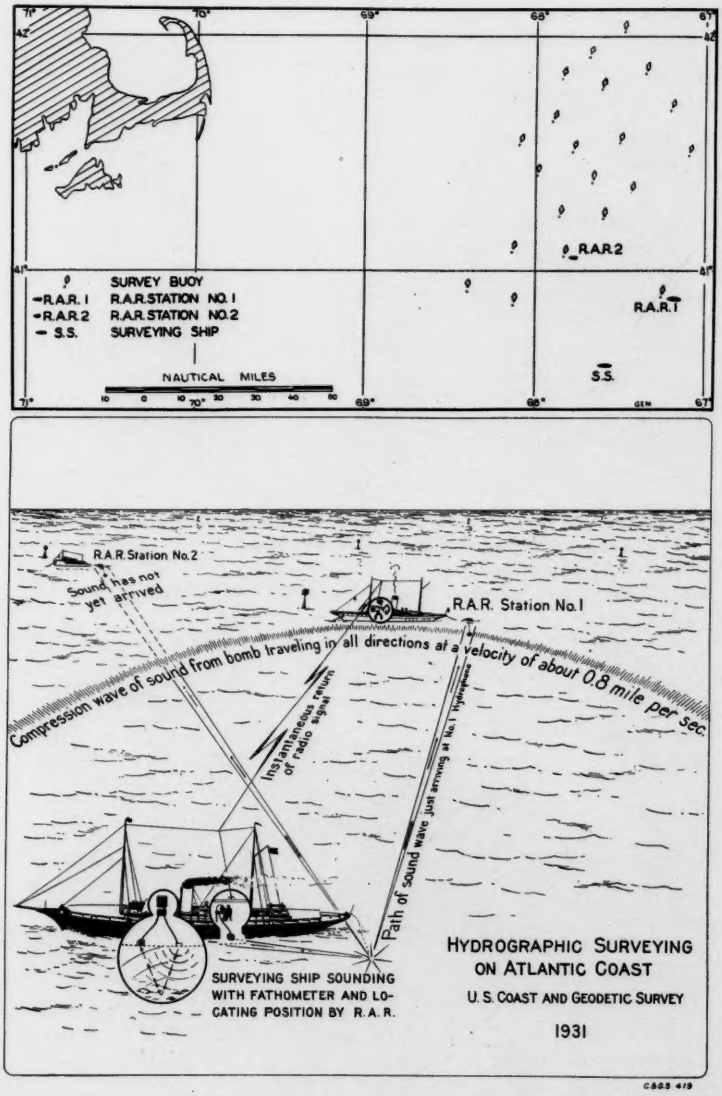

71°
70°
69°
68°
67°
42°
41°
R.A.R.2
R.A.R.T
S.S.
SURVEY BUOY
R.A.R. 1 R.A.R. STATION NO. 1
R.A.R.2 R.A.R. STATION NO. 2
S.S. SURVEYING SHIP
NAUTICAL MILES
10 0 10 20 30 40 60
GEN
R.A.R. Station No. 2
Sound has not yet arrived
R.A.R. Station No. 1
Compression wave of sound from bomb traveling in all directions at a velocity of about 0.8 mile per sec.
Instantaneous return of radio signal
Path of sound wave just arriving at No. 1 Hydrophone
SURVEYING SHIP SOUNDING WITH FATHOMETER AND LOCATING POSITION BY R.A.R.
HYDROGRAPHIC SURVEYING ON ATLANTIC COAST
U. S. COAST AND GEODETIC SURVEY
1931
C&GS 419

PLATE II

Fig. 1. Interior of electromagnetic type of hydrophone used exclusively for Radio Acoustic Ranging on the Atlantic Coast. Left to right: diaphragm, unit, closing plug, casing.

Fig. 2. Two-pen chronograph used for Radio Acoustic Ranging.

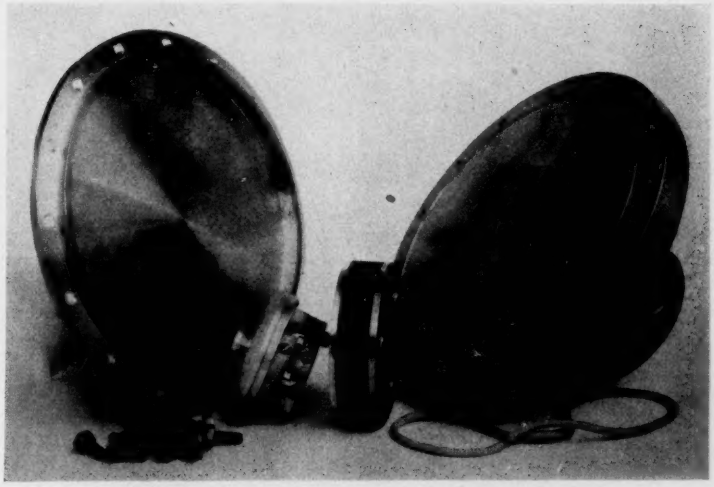


Fig. 1

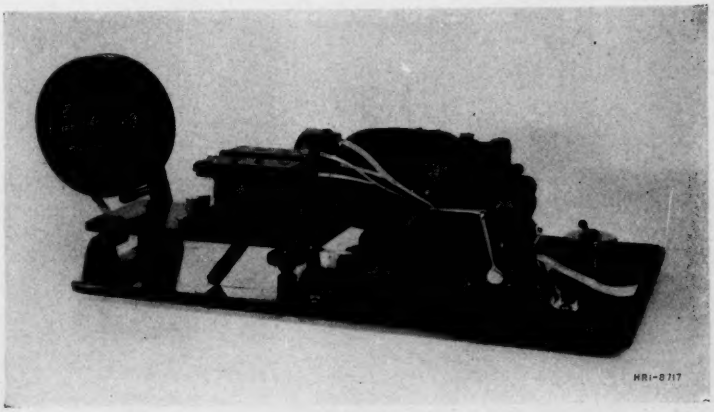


Fig. 2

PLATE III

Fig. 1. Planting a Sono Radio Buoy from *U. S. S. Hydrographer*.
Fig. 2. Wiring diagram of Sono Radio Buoy.

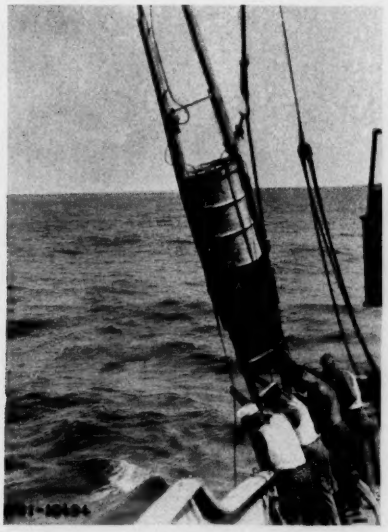


Fig. 1

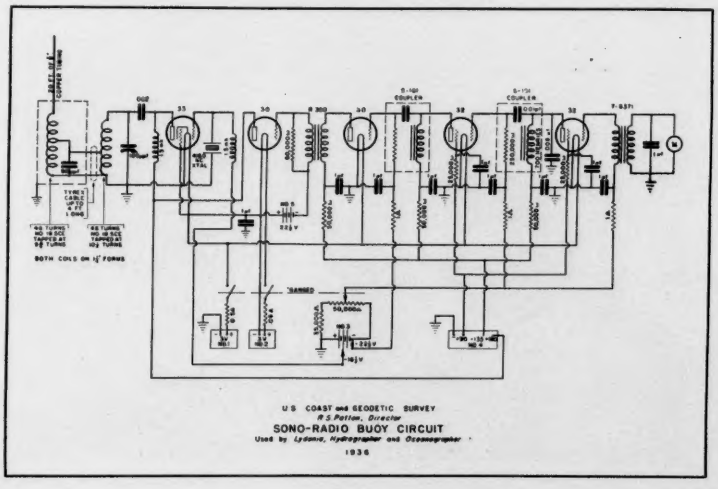

U S COAST and GEODETIC SURVEY
R S Patton, Director
SONO-RADIO BUOY CIRCUIT
1936

Fig. 2

PLATE IV

Fig. 1. Type 324 Oscillator used with Type 312 Fathometer.
Fig. 2. Interior of Type 324 Oscillator.

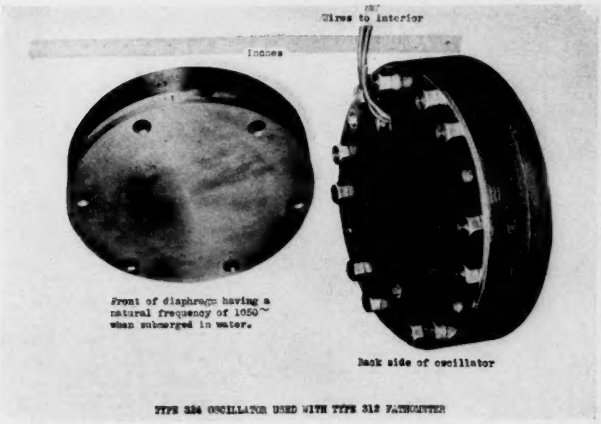

Wires to interior
Inches
Front of diaphragm having a natural frequency of 1050~ when submerged in water.
Back side of oscillator
TYPE 324 OSCILLATOR USED WITH TYPE 312 FATHOMETER

Fig. 1

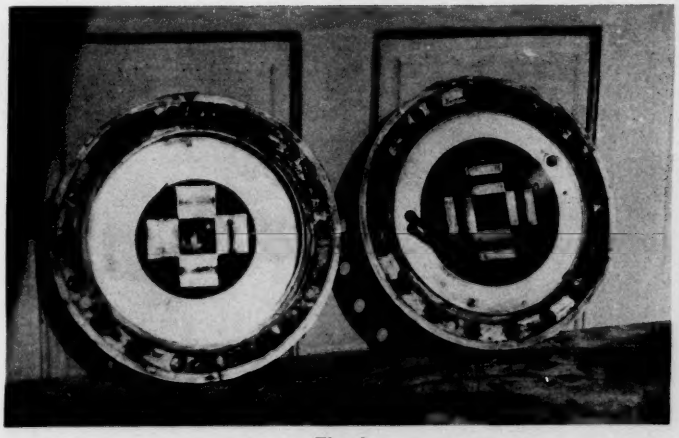


Fig. 2

PLATE V

Fig. 1. Standard circuit of Type 312 Fathometer, as used on U. S. Coast and Geodetic Survey ships.

Fig. 2. Schematic representation of operation of Dorsey Fathometer, Model I.

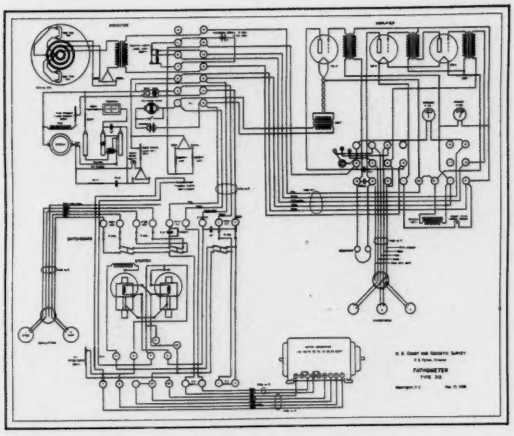


Fig. 1

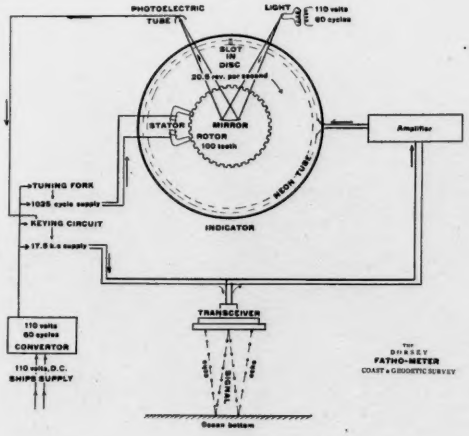

PHOTOELECTRIC TUBE
LIGHT
110 volts 60 cycles
SLOT IN DISC
STATOR
MIRROR
ROTOR 100 teeth
NEON TUBE
Amplifier
INDICATOR
TUNING FORK
1025 cycle supply
KEYING CIRCUIT
17.5 k.c. supply
TRANSCEIVER
110 volts 60 cycles CONVERTOR
110 volts, D.C. SHIPS SUPPLY
FATHO-METER
COAST & GEODETIC SURVEY
Ocean bottom

Fig. 2

PLATE VI

Fig. 1. Dorsey Fathometer, Model I, front view.
Fig. 2. Dorsey Fathometer, Model I, side view with front removed showing disc, neon tube, mirror, rotor and starting motor.

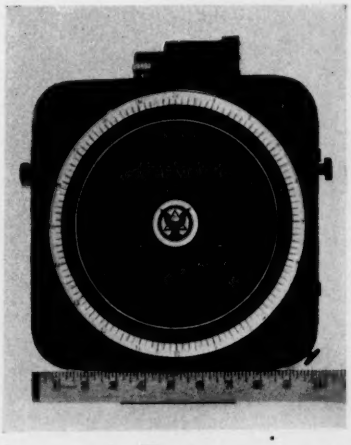


Fig. 1

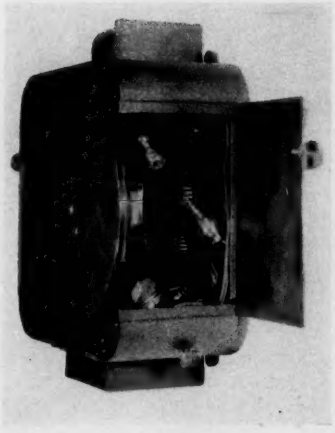


Fig. 2

PLATE VII

POWER SUPPLY CIRCUIT FOR DORSEY FATHOMETER

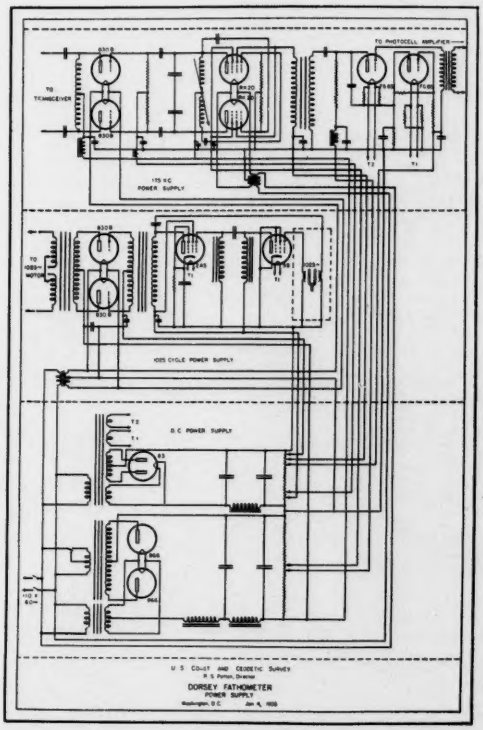

TO PHOTOCELL AMPLIFIER
TO TRANSCEIVER
175 K.C. POWER SUPPLY
TO 1000~ MOTOR
1025 CYCLE POWER SUPPLY
D.C. POWER SUPPLY
U. S. COAST AND GEODETIC SURVEY
R. S. Patton, Director
DORSEY FATHOMETER
POWER SUPPLY
Washington, D.C. Jan. 4, 1935

PLATE VIII

AMPLIFIER CIRCUIT FOR DORSEY FATHOMETER

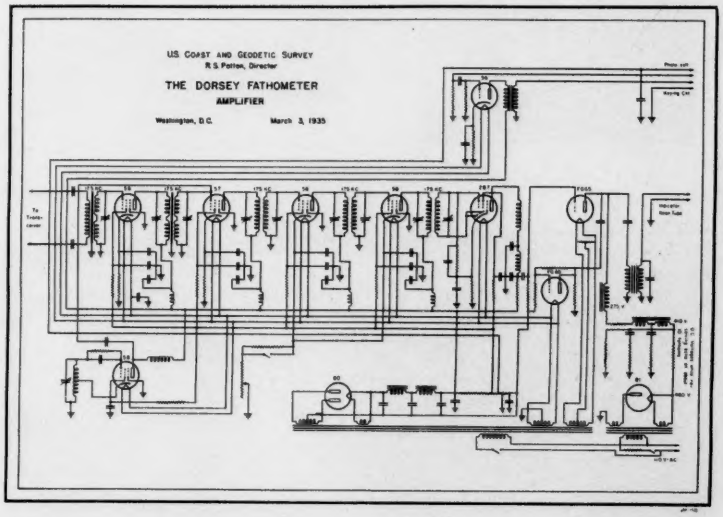

U.S. COAST AND GEODETIC SURVEY
R.S. Patton, Director
THE DORSEY FATHOMETER
AMPLIFIER
Washington, D.C. March 3, 1935

PLATE IX

Fig. 1. Dorsey Fathometer, Model II, front view.

Fig. 2. Dorsey Fathometer, Model II, with sides removed showing circular neon tube, arm with prism, stators, rotor and gears.

Fig. 3. Scene in pilot house of *U. S. S. Oceanographer* during hydrographic surveying.

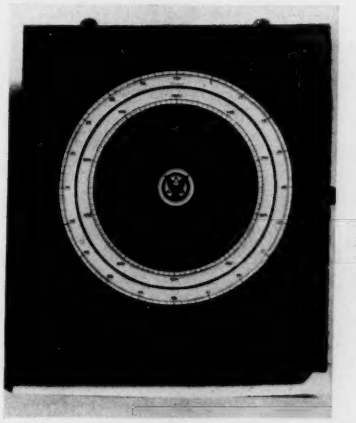


Fig. 1

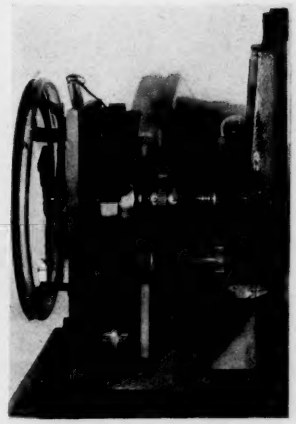


Fig. 2

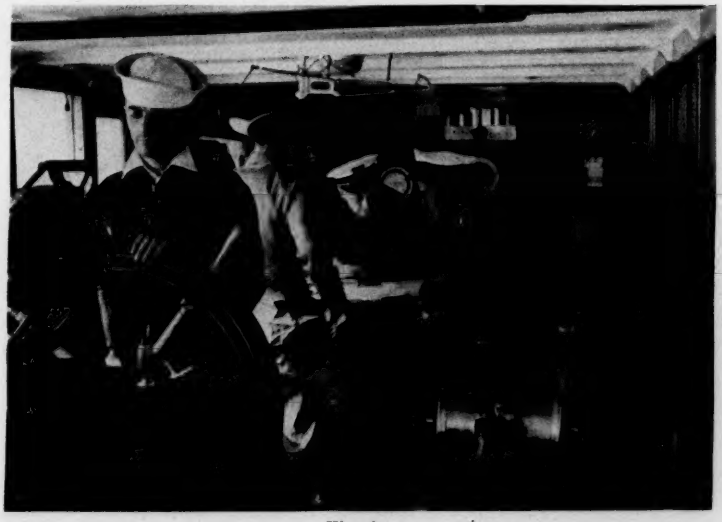
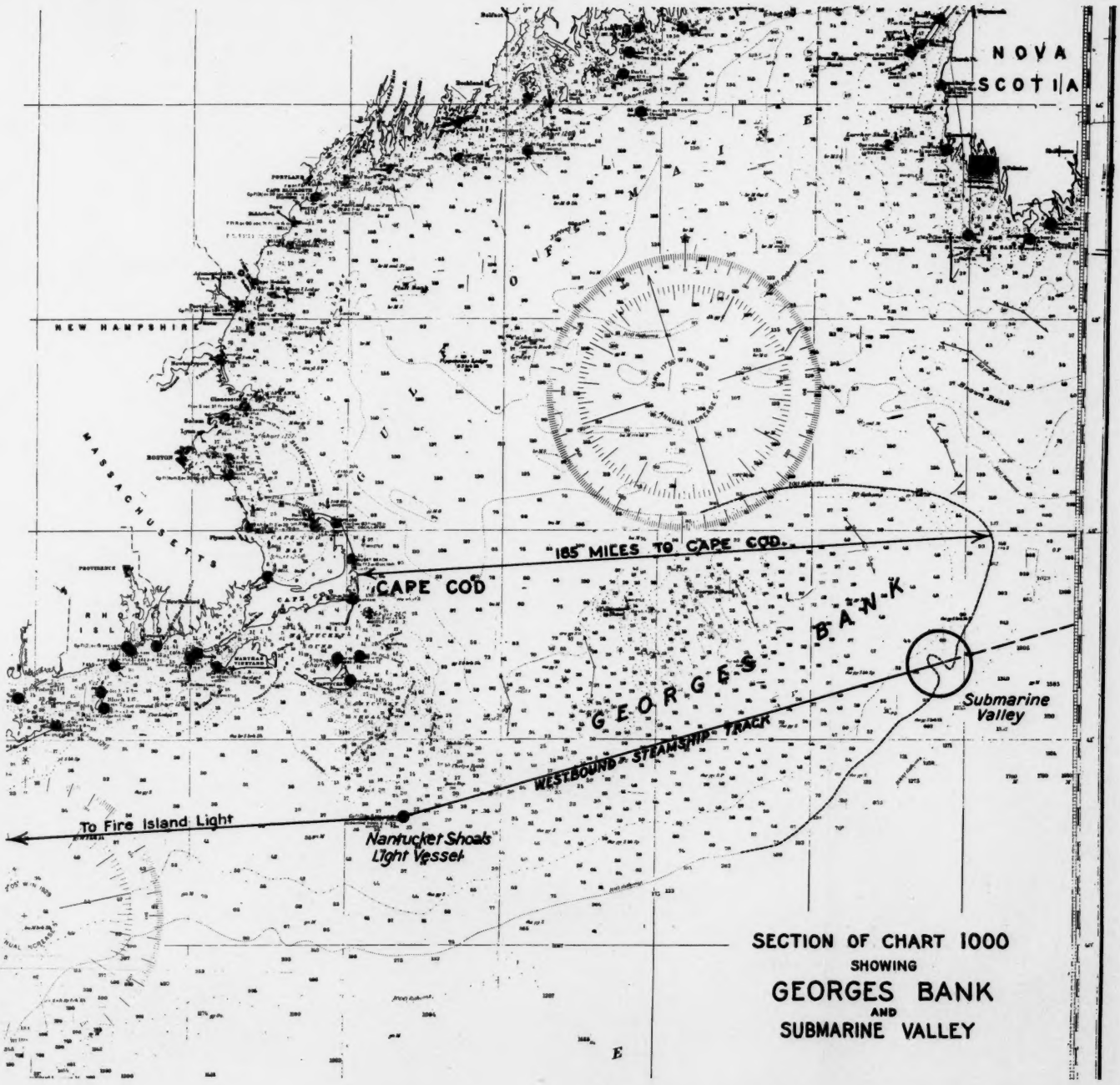


Fig. 3

PLATE X

CHART SHOWING HOW THE POSITION OF A SUBMARINE VALLEY MAY ACT AS AN AID TO NAVIGATION



SECTION OF CHART 1000
SHOWING
GEORGES BANK
AND
SUBMARINE VALLEY

AN ANNOTATED CHECK-LIST OF BIRDS RECORDED AT GRANVILLE, LICKING COUNTY, OHIO

WARD M. KLEPFER AND WILLIAM J. TAYLOR

Received June 17, 1937; published September 28, 1937

INTRODUCTION

In the following pages is presented an annotated check-list of the species and sub-species of birds recorded at Granville, Ohio, by the authors during the course of four years (1933–1937) spent in undergraduate study at Denison University. After each species there is given its local status and time of occurrence as determined from our records for this period, and in addition a brief statement of its general distribution. A list of this nature for a region where the avifauna are as well known as in central Ohio, finds justification, we believe, in its purpose, which is to encourage and assist students of Denison University and residents of Granville in the field study of our local birds.

With this aim in mind we have compiled a distinctly local list; all of the 184 species reported in this article except the Mockingbird have been seen within a mile of Granville. The places within this radius that are of most interest to the bird student are: (1) the Gravel Pit, a body of water about 400 yards in length south of Granville, and the small marshy area on the south side of the Gravel Pit, which we have termed the Sinks; (2) Lake Ebaugh, a small body of water on the north campus; (3) the portion of Raccoon Creek and its valley which lies south and south-east of Granville; (4) the area north-west of Granville which is bounded by, and including, Sunset Hill on the east, Thorne's Woods on the west, and the Cross-country Course (new and old Burg Streets) on the north and south; (5) Sugarloaf Hill and the wooded parts of the upper campus; and (6) Spring Valley.

Copyright 1937 Ward M. Klepfer and William J. Taylor.

The order and nomenclature of the American Ornithologists' Union Check List, 1931 edition, have been followed in this list. In stating the status of each bird, the terms "abundant, very common, common, fairly common, rather uncommon, uncommon, rather rare, rare, and very rare", provide an approximate idea of the frequency of occurrence of each species, with some allowance for the influence of conspicuousness and habitat on its apparent abundance.

Median dates of arrival and departure have been given in most cases; a few unusually early or late dates have been included in parentheses. An important consideration in connection with a check list for this restricted area is that the status of some species will vary from the general status in Licking County or central Ohio, and it is in such cases that the term "locally" has been applied to the status.

The following abbreviations have been used:

T.V., transient visitant
S.R., summer resident
P.R., permanent resident
W.R., winter resident

CHECK LIST

Horned grebe. *Colymbus auritus.* Rare T. V. One record at the Gravel Pit on May 2, 1935.

Pied-billed grebe. *Podilymbus podiceps podiceps.* Fairly common T. V. (Mar. 23) Mar. 30–May 2; Oct. 6–Nov. 9. A regular migrant on the Gravel Pit and Lake Ebaugh in the spring.

Great blue heron. *Ardea herodias herodias.* Uncommon T. V. Mar. 17–May 6. No fall records. Licking County lies on the southern limit of the breeding range of this heron in Ohio; occasional individuals occur at Granville during the summer.

Eastern green heron. *Butorides virescens virescens.* Fairly common S. R. Apr. 18–Sept. 18. Found at the Gravel Pit and Lake Ebaugh.

Black-crowned night heron. *Nycticorax nycticorax hoactli.* Uncommon T. V. Mar. 30–Apr. 14. No fall records. Spring records at the Gravel Pit.

American bittern. *Botaurus lentiginosus.* Rather rare T. V. Apr. 29–May 14. No fall records. Spring records at the Gravel Pit.

Canada goose. *Branta canadensis canadensis.* Uncommon T. V., passing over in March, late October, and November. A flock of about seventy, the largest noted, was seen on October 30, 1934.

Common mallard. *Anas platyrhynchos platyrhynchos.* Uncommon T. V. Mar. 9–Apr. 19. No fall records. Irregular at the Gravel Pit in small numbers.

Common black duck. *Anas rubripes tristes.* Rare T. V. locally. Two individuals were recorded at the Gravel Pit on March 29, 1937.

Baldpate. *Mareca americana.* Fairly common T. V. Mar. 8–Apr. 23. No fall records. This species occurs here in larger numbers than any other duck except perhaps the Blue-winged Teal.

Green-winged teal. *Nettion carolinense.* Rather rare T. V. Mar. 21–28. No fall records. Noted on the Gravel Pit.

Blue-winged teal. *Querquedula discors.* Fairly common T. V. (Mar. 30) Apr. 9–May 2. No fall records. Occurs regularly at the Gravel Pit and Lake Ebaugh.

Shoveller. *Spatula clypeata.* Rare T. V. locally. Mr. John Chapin reports that he recorded this species on the Gravel Pit on March 19 and April 8, 1936.

Ring-necked duck. *Nyroca collaris.* Fairly common T. V. (Mar. 9) Mar. 22–Apr. 25. One fall record of two females on October 9, 1935. A regular migrant in small numbers on the Gravel Pit and Lake Ebaugh.

Canvasback. *Nyroca valisineria.* Rare T. V. locally. A male of this species remained on the Gravel Pit from March 29 to April 11, 1937.

Lesser scaup duck. *Nyroca affinis.* Fairly common T. V. Mar. 24–May 3. No fall records. Occurs regularly at the Gravel Pit and Lake Ebaugh.

American golden-eye. *Glaucionetta clangula americana.* Uncommon T. V. Mar. 29–Apr 10. No. fall records. Recorded on the Gravel Pit.

Buffiehead. *Charitonetta albeola.* Rare T. V. Mar. 12–May 2. No fall records. Irregular on the Gravel Pit.

Old-squaw. *Clangula hyemalis.* Rare T. V. A male of this species was recorded on the Gravel Pit on April 16, 1937.

Ruddy duck. *Erismatura jamaicensis rubida.* Rare T. V. Two females have been recorded on the Gravel Pit; one on May 2, 1935, and the other on April 18, 1936.

Hooded merganser. *Lophodytes cucullatus.* Rather uncommon T. V. Mar. 20–Apr. 18. No fall records. Recorded on the Gravel Pit.

American merganser. *Mergus merganser americanus.* Rare T. V. locally. One female recorded on the Gravel Pit on April 10, 1937, and several migrating birds noted during February, 1936.

Red-breasted merganser. *Mergus serrator.* Rare T. V. Apr. 4–May 3. No fall records. Occasional on the Gravel Pit.

Turkey vulture. *Cathartes aura septentrionalis.* Common S. R. (Feb. 26) Mar. 20–Oct. 18. Generally distributed with the largest concentrations over wooded areas.

Sharp-shinned hawk. *Accipiter velox velox.* Rare T. V., very rare P. R. Most frequent in March.

Cooper's hawk. *Accipiter cooperi.* Uncommon P. R. A few individuals are present throughout the year. In the winter this species often remains in the vicinity of a favorable roosting site and may be observed frequently.

Eastern Red-tailed hawk. *Buteo borealis borealis.* Uncommon P. R. This is the only species of this genus that has been noted regularly

Northern red-shouldered hawk. *Buteo lineatus lineatus.* Rare S. R., very rare or absent in winter.

Broad-winged hawk. *Buteo platypterus platypterus.* Rare and irregular T. V. The few individuals noted were seen from April 20 to May 20 in wooded areas.

Marsh hawk. *Circus hudsonius.* Uncommon P. R., irregular in summer. Generally seen in open country.

Osprey. *Pandion haliaetus carolinensis.* Very rare T. V. locally. Two records at the Gravel Pit: April 25, 1934, and April 22, 1936.

Eastern sparrow hawk. *Falco sparverius sparverius.* Fairly common P. R. Generally distributed and frequently conspicuous on the campus.

Bob-white. *Colinus virginianus virginianus.* Common P. R. Generally distributed, with its habitat varying with the season. This species is reduced in numbers following severe winters.

Ring-necked pheasant. *Phasianus colchicus torquatus.* This species occurs in numbers at Sunset Hill, where there is suitable cover and hunting is prohibited, but elsewhere it is a rather uncommon permanent resident.

Sora. *Porzana carolina.* Rare T. V. locally. Two records at the Sinks: April 28 and May 16, 1934.

American coot. *Fulica americana americana.* Fairly common T. V. Mar. 28–May 7. No fall records. A regular migrant on the Gravel Pit in small numbers.

Semipalmated plover. *Charadrius semipalmatus.* Rare T. V. A flock of about fifty was noted in a flooded field west of Granville on May 12, 1935.

Killdeer. *Oxyechus vociferus vociferus.* Common S. R. (Feb. 26) Mar. 2–Oct. 23 (Dec. 1). Inhabits pastures and cultivated fields, particularly those near water.

Woodcock. *Philohela minor.* Uncommon S. R. Mar. 15–May 13. This bird breeds in April and is probably present until October, although we have no record after May 13. Its habitat is restricted to moist areas in wooded tracts, such as may be found below Sunset Hill and at Spring Valley.

Wilson's snipe. *Capella delicata.* Fairly common T. V. Mar. 29–May 12. No fall records. Occurs about wet grassy drainage basins in open fields, particularly at the Sinks and along the Cross-country Course.

Upland plover. *Bartramia longicauda.* Rare T. V. locally. Apr. 13–May 6. No fall records. An irregular transient at Granville, although a breeding bird in parts of Licking County.

Spotted sandpiper. *Actitis macularia.* Common T. V., fairly common S. R. Apr. 15–Sept. 26. Most numerous at the Gravel Pit and along Raccoon Creek.

Eastern solitary sandpiper. *Tringa solitaria solitaria.* Common T. V. Apr. 13–May 15. Uncommon in the fall. Sept. 9–17. Occurs at the Sinks and the Gravel Pit.

Greater yellow-legs. *Totanus melanoleucus.* Uncommon T. V. Apr. 11–May 2. No fall records. Noted only at the Sinks.

Lesser yellow-legs. *Totanus flavipes.* Fairly common T. V. Apr. 13–May 6. No fall records. Occurs at the Sinks, occasionally in flocks of a dozen or more.

Pectoral sandpiper. *Pisobia melanota.* Rather uncommon T. V. Mar. 30–May 8. No fall records. Occurs in small numbers at the Sinks. A flock of forty was seen just west of Thorne's Woods on April 26, 1936.

Least sandpiper. *Pisobia minutilla.* Rare T. V. Two records at the Gravel Pit: May 6, 1934, and May 5, 1935.

Semipalmated sandpiper. *Ereunetes pusillus.* Rare T. V. One individual was noted in a flooded field west of Granville on May 12, 1935.

Herring gull. *Larus argentatus smithsonianus.* Rare T. V. locally. Two records at the Gravel Pit: March 14 and April 3, 1935.

Ring-billed gull. *Larus delawarensis.* Rare T. V. locally. Two migrating birds were noted April 24, 1937.

Common tern. *Sterna hirundo hirundo.* Rare T. V. locally. Two records of individuals at the Gravel Pit on May 2, 1935, and May 12, 1937.

Black tern. *Chlidonias nigra surinamensis.* Rare T. V. Two migrating birds were noted on May 3, 1935.

Eastern mourning dove. *Zenaidura macroura carolinensis.* Very common S. R. March–October. Uncommon W. R. Found about open woods and lawns in the summer; most frequent in grain fields in the winter.

Yellow-billed cuckoo. *Coccyzus americanus americanus.* Fairly common S. R. May 10–Oct. 4. Frequents thickets and the borders of wooded streams.

Black-billed cuckoo. *Coccyzus erythrophthalmus.* Fairly common T. V., uncommon S. R. May 1–Oct. 4. Frequents thickets and the borders of wooded streams.

Eastern screech owl. *Otus asio naevius.* Fairly common P. R. Generally distributed in woodlands; often noted in town.

Great horned owl. *Bubo virginianus virginianus.* Uncommon P. R. Found in heavily wooded areas.

Northern barred owl. *Strix varia varia.* Rather uncommon P. R. Found chiefly in wooded tracts, such as Thorne's Woods.

Common saw-whet owl. *Cryptoglaux acadica acadica.* Rare W. R., possibly a S. R. One individual was recorded on the Upper Campus on February 28, 1937.

Eastern whip-poor-will. *Antrostomus vociferus vociferus.* Uncommon and irregular S. R. Apr. 26. No fall records. This nocturnal species spends the day concealed in woodland thickets.

Eastern nighthawk. *Chordeiles minor minor.* Fairly common T. V. locally. May 8–21; Sept. 1–23. Casual in summer. Often noted toward evening during migration.

Chimney swift. *Chaetura pelagica.* Abundant S. R. Apr. 8–Oct. 26. This species is always conspicuous during the summer months with large concentrations occuring near suitable chimneys.

Ruby-throated hummingbird. *Archilochus colubris.* Fairly common S. R. May 8–Sept. 6. Rather generally distributed in woodlands and about gardens.

Eastern belted kingfisher. *Megaceryle alcyon alcyon.* Fairly common S. R. Mar. 12–Oct. 6 (Dec. 4). Conspicuous along Raccoon Creek, the Gravel Pit, and Lake Ebaugh.

Northern flicker. *Colaptes auratus luteus.* Very common S. R. Mar. 9–Nov. 18. Rather uncommon W. R. Generally distributed in woods and partially wooded areas.

Red-bellied woodpecker. *Centurus carolinus.* Fairly common P. R. Generally distributed in wooded areas.

Red-headed woodpecker. *Melanerpes erythrocephalus.* Uncommon S. R. Apr. 16–Sept. 30. Irregular and rather rare W. R. Found in woods and partially wooded areas.

Yellow-bellied sapsucker. *Sphyrapicus varius varius.* Fairly common T. V. (Mar. 6) Mar. 25–May 12; Oct. 1–28 (Nov. 18). Occurs in open woodlands.

Eastern hairy woodpecker. *Dryobates villosus villosus.* Fairly common P. R. Generally distributed in wooded areas.

Northern downy woodpecker. *Dryobates pubescens medianus.* Common P. R. Found in woods and partially wooded areas.

Kingbird. *Tyrannus tyrannus.* Common T. V., uncommon S. R. Apr. 24. No fall records. Usually found near water during migration.

Northern crested flycatcher. *Myiarchus crinitus boreus.* Common S. R. Apr. 24–Sept. 17. Restricted to wooded areas.

Eastern phoebe. *Sayornis phoebe.* Common S. R. Mar. 13–Oct. 6. Confined to the vicinity of streams and ponds except during migrations.

Yellow-bellied flycatcher. *Empidonax flaviventris.* Rare T. V. Two records: May 12 and 16, 1934. Both birds were noted in dense woods.

Acadian flycatcher. *Empidonax virescens.* Uncommon S. R. (Apr. 29) May 16. No fall records. General in woodlands during migration, but recorded only in Thorne's Woods in the Summer. Positive identification during migration of this and the two succeeding species can only be made on the basis of their notes.

Alder flycatcher. *Empidonax trailli trailli.* Fairly common S. R. May 13–Sept. 6. Breeding pairs have been noted at Lake Ebaugh and the Columbus Viaduct.

Least flycatcher. *Empidonax minimus.* Common T. V. May 3–20. One fall record, September 19. Generally found in clearings and open woodlands.

Eastern wood pewee. *Myiochanes virens.* Common S. R. May 6–Sept. 26. General in woodlands.

Olive-sided flycatcher. *Nuttallornis mesoleucus.* Rare T. V. One record at the Gravel Pit on September 6, 1935.

Northern horned lark. *Otocoris alpestris alpestris.* Uncommon W. R. Nov. (?) Dec. 1–Feb. 13. Mar. (?). On January 26, 1935, a flock of three hundred horned larks, mostly of this species, was observed along the Cross-country Course. However this species is apparently irregular in the hilly region surrounding Granville.

Prairie horned lark. *Octoris alpestris practicola.* Fairly common S. R. March–November. Rare W. R. Inhabits pastures and plowed fields.

Tree swallow. *Iridoprocne bicolor.* Common T. V. locally. Apr. 15–May 18. No fall records. Noted at the Gravel Pit and Lake Ebaugh, where on cold days during their migration, concentrations of Tree, Rough-winged, and Barn Swallows often occur.

Bank swallow. *Riparia riparia riparia.* Uncommon T. V. Apr. 17–May 11. No fall records. An irregular migrant in the company of Rough-winged Swallows.

Rough-winged swallow. *Stelgidopteryx ruficollis serripennis.* Very common T. V., common S. R. Apr. 14–Aug. Occurs at the Gravel Pit, Lake Ebaugh, and along Raccoon Creek.

Barn swallow. *Hirundo erythrogaster.* Very common T. V., common S. R. Apr. 13–Sept. 25. Generally distributed over farmland and water.

Northern cliff swallow. *Petrochelidon albifrons albifrons.* Uncommon T. V. Apr. 18–May 4. One fall record, September 20, 1936. An occasional individual of this species may be noted among the groups of swallows at the Gravel Pit and Lake Ebaugh.

Purple martin. *Progne subis subis.* Common S. R. Apr. 7–Sept. 18. Rather generally distributed during migration, but during the summer usually seen flying in the vicinity of the martin houses where they breed.

Blue jay. *Cyanocitta cristata cristata.* Common P. R. General in wooded areas.

Eastern crow. *Corvus brachyrhynchos brachyrhynchos.* Very common S. R. Mar.–Nov. Common W. R. Generally distributed, but more numerous in outlying sections.

Carolina chickadee. *Penthestes carolinensis carolinensis.* Common P. R. Generally distributed in and about wooded areas.

Tufted titmouse. *Baeolophus bicolor.* Common P. R. Decidedly a woodland bird during the summer; more general in the winter.

Northern white-breasted nuthatch. *Sitta carolinensis carolinensis.* Common P. R. Generally distributed in wooded areas.

Red-breasted nuthatch. *Sitta canadensis.* Uncommon T. V., rare and irregular W. R. Sept. 18–May 16. Occurs in wooded areas.

Brown creeper. *Certhia familiaris americana.* Common T. V., fairly common W. R. Oct. 2–Apr. 28. General in wooded areas.

House wren. *Troglodytes aedon aedon.* Common S. R. Apr. 17–Sept. 25. Found chiefly near dwellings during the nesting season, but in the fall it occurs more frequently in thickets and woodlands.

Eastern winter wren. *Nannus hiemalis hiemalis.* Fairly common T. V. Mar. 29–Apr. 30. Two fall records, October 3 and 25. Prefers brush tangles in wet, wooded areas such as exist below Sunset Hill.

Bewick's wren. *Thryomanes bewicki bewicki.* Uncommon S. R. Apr. 9. No fall records. This species nests early and is less conspicuous after the middle of May. It is found about outlying buildings and dwellings.

Carolina wren. *Thryothorus ludovicianus ludovicianus.* Normally a common permanent resident but greatly reduced in numbers following severe winters. The resident population was practically exterminated by the winter of 1935–1936 and this species is still uncommon. Rather generally distributed but more frequent about low wooded areas such as along Racoon Creek.

Mockingbird. *Mimus polyglottos polyglottos.* Rare P. R. Although this species has not been observed strictly within the limits of this territory, a few individuals have been recorded within two miles of Granville.

Catbird. *Dumetella carolinensis.* Common S. R. Apr. 23–Oct. 4. Generally distributed in dense thicket growths.

Brown thrasher. *Toxostoma rufum.* Fairly common S. R. (Apr. 9) Apr. 14–Sept. 26. A thicket inhabiting species occuring about the margins of woods and fields.

Eastern robin. *Turdus migratorius migratorius.* Abundant S. R. Feb. 21–Nov. 18. Rare W. R. Generally distributed except in deep woods.

Wood thrush. *Hylocichla mustelina.* Common S. R. Apr. 28–Oct. 3. Generally distributed in woodlands.

Eastern hermit thrush. *Hylocichla guttata faxoni.* Very common T. V. Apr. 2–May 2; Oct. 2–20. Occurs in wooded areas.

Olive-backed thrush. *Hylocichla ustulata swainsoni.* Very common T. V. Apr. 28–May 26; Oct. 4–13. Occurs in wooded and partially wooded areas.

Gray-cheeked thrush. *Hylocichla minima aliclae.* Common T. V. Apr. 28–May 20; Sept. 6–24. Occurs in wooded areas.

Veery. *Hylocichla fuscescens fuscescens.* Common T. V. Apr. 28–May 21; Sept. 10–24. Occurs in wooded areas.

Eastern bluebird. *Sialia sialis sialis.* Common S. R. (Feb. 26) Mar. 1–Oct. 6. Generally distributed in open country.

Blue-gray gnatcatcher. *Polioptila caerulea caerulea.* Fairly common S. R. Apr. 15. No fall records. Occurs in wooded areas, usually in the upper foliage.

Golden-crowned kinglet. *Regulus satrapa satrapa.* Fairly common T. V. Mar. 29–Apr. 25; Oct. 3–Nov. 18. Uncommon to rare W. R. General in wooded areas, preferring coniferous trees.

Eastern ruby-crowned kinglet. *Corthylio calendula calendula.* Common T. V. (Apr. 6) Apr. 13–May 14; Sept. 17–Oct. 15. General in wooded areas.

American pipit. *Anthus spinoletta rubescens.* Common T. V. Mar. 29–May 5. One fall record on October 6. Frequents meadows and plowed fields. Flocks as large as four hundred of these birds have been seen along the cross country course.

Cedar waxwing. *Bombycilla cedrorum.* Common S. R. Apr. 12–Oct. 23. Rare W. R. Generally distributed in open woodlands.

Migrant shrike. *Lanius ludovicianus migrans.* Fairly common S. R. Mar. 16. No fall records. Found about hedges and thorn trees in rather open country.

Starling. *Sturnus vulgaris vulgaris.* Abundant P. R. Generally distributed.

White-eyed vireo. *Vireo griseus griseus.* Uncommon T. V. Apr. 29–May 17. No fall records. Inhabits thicket growths. Observed most frequently about the Gravel Pit.

Yellow-throated vireo. *Vireo flavifrons.* Rather uncommon S. R. Apr. 30–Sept. 20. Found in woodlands, preferring the tops of the larger trees.

Blue-headed vireo. *Vireo solitarius solitarius.* Fairly common T. V. Apr. 30–May 16 (May 19). No fall records, but undoubtedly a migrant in September. Occurs in woods.

Red-eyed vireo. *Vireo olivaceus.* Common S. R. Apr. 28–Oct. 3. Generally distributed in woodland and shade trees.

Philadelphia vireo. *Vireo philadelphicus.* Rare T. V. May 1–17. One fall record October 3. Occurs in wooded areas.

Eastern warbling vireo. *Vireo gilvus gilvus.* Common S. R. Apr. 24–Sept. 14. Prefers the tops of larger trees, particularly those near water.

Black and white warbler. *Mniotilta varia.* Common T. V. Apr. 24–May 16; Sept. 6–26. Occurs in wooded areas.

Prothonotary warbler. *Protonotaria citrea.* Rare T. V. locally. A pair was noted along Raccoon Creek from May 6 to May 13, 1934.

Worm-eating warbler. *Helmitheros vermivorus.* Rare T. V. locally. Mr. John Chapin reports that he recorded this species at Thorne's Woods on May 10, 1936.

Golden-winged warbler. *Vermivora chrysoptera.* Rare T. V. One record on the Upper Campus on May 14, 1937.

Blue-winged warbler. *Vermivora pinus.* Fairly common T. V. May 1–18. One fall record September 19. Possibly a rare summer resident. Found in open woodlands, generally ranging rather low in the trees.

Tennessee warbler. *Vermivora peregrina.* Common T. V. May 1–23; Sept. 13–Oct. 4. Occurs in wooded areas.

Nashville warbler. *Vermivora ruficapilla ruficapilla.* Common T. V. Apr. 30–May 22; Sept. 14–Oct. 4. Generally distributed in wooded areas.

Northern parula warbler. *Compsothlypis americana pusilla.* Fairly common T. V. May 7–19. One fall record September 26. Found in woodlands, preferring the tops of the larger trees.

Eastern yellow warbler. *Dendroica aestiva aestiva.* Very Common S. R. Apr. 22–Sept. 14. Found about the borders of streams and ponds, and also in shade trees and shrubbery near dwellings.

Magnolia warbler. *Dendroica magnolia.* Common T. V. May 6–23; Sept. 17–30. Occurs in wooded areas.

Cape May warbler. *Dendroica tigrina.* Uncommon T. V. May 2–18. No fall records. Occurs in wooded areas.

Black-throated blue warbler. *Dendroica caerulescens caerulescens.* Common T. V. May 6–16; Sept. 13–27. Found in wooded areas.

Myrtle warbler. *Dendroica coronata.* Very common T. V. Apr. 18–May 17; Sept. 25–Oct. 31. Found in partially wooded areas.

Black-throated green warbler. *Dendroica virens virens.* Very common T. V. Apr. 22–May 22; Sept. 12–Oct. 18. Occurs in wooded areas.

Cerulean warbler. *Dendroica cerulea.* Fairly common T. V. locally. Apr. 30–May 15. No fall records. Occurs in woodlands, preferring the tops of the larger trees.

Blackburnian warbler. *Dendroica fusca.* Common T. V. May 1–21; Sept. 19–Oct. 2. Found in wooded areas.

Chestnut-sided warbler. *Dendroica pensylvanica.* Common T. V May 1–23; Sept. 17–Oct. 3. Found in wooded and partially wooded areas.

Bay-breasted warbler. *Dendroica castanea.* Common T. V. May 6–23; Sept. 20–Oct. 4. Found in wooded areas.

Black-poll warbler. *Dendroica striata.* Common T. V. (Apr. 29) May 12–25; Sept. 12–Oct. 6. Found in wooded areas.

Palm warbler. *Dendroica palmarum palmarum.* Common T. V. Apr. 26–May 16; Sept. 20–Oct. 6. Observed most frequently at the Gravel Pit.

Oven-bird. *Seiurus aurocapillus.* Common T. V., rather uncommon S. R. Apr. 29–Oct. 3. Found in woodlands.

Grinnell's water-thrush. *Seiurus noveboracensis notabilis.* Uncommon T. V. Apr. 24–May 13. No fall records. Occurs along Raccoon Creek and the Gravel Pit.

Louisiana water-thrush. *Seiurus motacilla.* Common T. V. Apr. 19–May 16; Sept. 26. Frequents the undergrowth near streams and ponds, particularly at the Gravel Pit.

Kentucky warbler. *Oporornis formosus.* Common T. V. Apr. 28–May 26. No fall records. Most frequent in moist thicket areas in woodlands.

Mourning warbler. *Oporornis philadelphia.* Rare T. V. One record May 9, 1936, on Sugarloaf Hill.

Northern yellow-throat. *Geothlypis trichas brachidactyla.* Very common S. R. Apr. 28–Oct. 3. Frequents undergrowth and thickets near water and moist ground.

Yellow-breasted chat. *Icteria virens virens.* Common S. R. Apr. 29–Sept. 12. Inhabits dense bramble and thicket growths in fields and at the borders of woods.

Hooded warbler. *Wilsonia citrina.* Rather rare T. V. May 7–14. No fall records. Frequents the undergrowth in woodlands.

Wilson's warbler. *Wilsonia pusilla pusilla.* Fairly common T. V. May 7–16. One fall record September 16. Occurs at the Gravel Pit and Lake Ebaugh.

Canada warbler. *Wilsonia canadensis.* Fairly common T. V. May 6–19; Sept. 11–20. Found in wooded areas.

American redstart. *Setophaga ruticilla.* Common T. V. locally. May 1–26; Sept. 6–19. Occurs in wooded areas.

English sparrow. *Passer domesticus domesticus.* Abundant P. R. Generally distributed about dwellings and farms.

Bobolink. *Dolichonyx oryzivorus.* Uncommon S. R. Apr. 25–Oct. 4. Inhabits fields and meadows, particularly those near streams.

Eastern meadowlark. *Sturnella magna magna.* Very common S. R. Feb. 28–Dec. 1. Uncommon W. R. General in fields and meadows.

Eastern red-winged blackbird. *Agelaius phoeniceus phoeniceus.* Very common T. V., fairly common S. R. Feb. 26–Oct. 31. Most frequent at the Gravel Pit and Lake Ebaugh.

Orchard oriole. *Icterus spurius.* Uncommon T. V. locally. May 3–25. No fall records. Noted along Raccoon Creek and occasionally in shade trees in town.

Baltimore oriole. *Icterus galbula.* Common S. R. Apr. 25–Sept. 12. Found in shade trees and orchards.

Rusty blackbird. *Euphagus carolinus.* Fairly common T. V. Mar. 19–May 12; Sept. 21–Oct. 12. Occurs near ponds and swampy areas.

Bronzed grackle. *Quiscalus quiscula aeneus.* Very common S. R. Feb. 28–Dec. 31. Rare W. R. Occurs near farms and dwellings, preferring coniferous trees.

Cowbird. *Molothrus ater ater.* Very common S. R. Mar. 11–Oct. 13. General about farms and pastures.

Scarlet tanager. *Piranga erythromelas.* Fairly common S. R. May 1–Sept. 17. Found in woodlands.

Eastern cardinal. *Richmondena cardinalis cardinalis.* Common P. R. Found about thickets and shrubbery near dwellings and in partially wooded areas.

Rose-breasted grosbeak. *Hedymeles ludovicianus.* Fairly common T. V. Apr. 28–May 16; Sept. 12. Found in woodlands.

Indigo bunting. *Passerina cyanea.* Very common S. R. May 1–Oct. 6. Found in thicket and bramble growths in partially wooded areas, often near streams.

Eastern evening grosbeak. *Hesperiphona vespertina vespertina.* Very rare and irregular W. R. One record of one individual at Sunset Hill on December 1, 1935.

Eastern purple finch. *Carpodacus purpureus purpureus.* Fairly common T. V. Apr. 18–May 12. No fall records. Occurs in partially wooded areas.

Eastern goldfinch. *Spinus tristis tristis.* Very common S. R. Apr. 10–Oct. 15. Uncommon and irregular W. R. Found about clearings and weed patches in old fields.

Red-eyed towhee. *Pipilo erythrophthalmus erythrophthalmus.* Common S. R. (Feb. 22) Mar. 3–Dec. 1. Uncommon W. R. Frequents leafy undergrowth in partially wooded areas.

Eastern savannah sparrow. *Passerculus sandwichensis savanna.* Common T. V. Mar. 22–May 13; Sept. 20–Oct. 18. Possibly breeds locally, as indicated by one record on May 26. Occurs in both wet, marshy meadows and dry fields.

Eastern grasshopper sparrow. *Ammodramus savannarum australis.* Very common S. R. Apr. 18–Sept. 17. Found in dry fields.

Western henslow's sparrow. *Passerherbulus henslowi henslowi.* Rare T. V. Apr. 9–May 12. No fall records. Found both in dry fields and in swampy areas.

Eastern vesper sparrow. *Pooecetes gramineus gramineus.* Common S. R. Mar. 24–Oct. 14 (Dec. 1). Found in dry fields.

Bachman's sparrow. *Aimophila aestivalis bachmani.* Rare S. R. One individual was recorded west of Sunset Hill on April 29, 1937.

Slate-colored junco. *Junco hyemalis hyemalis.* Very common T. V., common W. R. Oct. 3–Apr. 27 (May 8). Frequents the borders of woods and fields.

Eastern tree sparrow. *Spizella arborea arborea.* Very common W. R. Oct. 31–Apr. 24. Found in bushes and thickets in fields and open woodlands.

Eastern chipping sparrow. *Spizella passerina passerina.* Common S. R. Mar. 25–Oct. 8. Occurs near dwellings during the nesting season; more general in the fall.

Field sparrow. *Spizella pusilla pusilla.* Abundant S. R. Mar. 20–Oct. 10. Frequents pastures and old fields, particularly about thickets and brambles.

White-crowned sparrow. *Zonotrichia leucophrys leucophrys.* Fairly common T. V. Apr. 24–May 18; Oct. 10–23. Found generally in thickets and underbrush.

White-throated sparrow. *Zonotrichia albicollis.* Very common T. V. Apr. 22–May 18; Sept. 25–Oct. 23. Occurs about woodland thickets.

Fox sparrow. *Passerella iliaca iliaca.* Fairly common T. V. Mar. 16–Apr. 24; Oct. 13–28. Frequents thickets at the borders of fields and woods.

Lincoln's sparrow. *Melospiza lincolni lincolni.* Rare T. V. One record at the Sinks, on May 12, 1937, of a singing bird.

Swamp sparrow. *Melospiza georgiana.* Fairly common T. V. locally. Mar. 25–May 6; Oct. 2–23. Found in underbrush near water and in wet fields.

Mississippi song sparrow. *Melospiza melodia beata.* Common W. R., abundant S. R. Generally distributed in thicket growths, especially near water.

INDEX

Accipiter cooperi ... 190
velox velox ... 190
Actitis macularia ... 192
Agelaius phoeniceus phoeniceus ... 201
Aimophila aestivalis bachmani ... 202
Ammodramus savannarum australis ... 202
Anas platyrhynchos platyrhynchos ... 189
rubripes tristes ... 189
Anthus spinoletta rubescens ... 197
Antrostomus vociferus vociferus ... 193
Archilochus colubris ... 193
Ardea herodias herodias ... 188

Baeolophus bicolor ... 196
Baldpate ... 189
Bartramia longicauda ... 191
Bittern, American ... 189
Blackbird, Eastern Red-winged ... 201
Rusty ... 201
Bluebird, Eastern ... 197
Bobolink ... 201
Bob-white ... 191
Bombycilla cedrorum ... 197
Botaurus lentiginosus ... 189
Branta canadensis canadensis ... 189
Bubo virginianus virginianus ... 193
Bufflehead ... 190
Bunting, Indigo ... 201
Buteo borealis borealis ... 190
lineatus lineatus ... 190
platypterus platypterus ... 190
Butorides virescens virescens ... 188

Canvasback ... 189
Capella delicata ... 191
Cardinal, Eastern ... 201
Carpodacus purpureus purpureus ... 202
Catbird ... 196
Cathartes aura septentrionalis ... 190
Centurus carolinus ... 193
Certhia familiaris americana ... 196
Chaetura pelagica ... 193
Charadrius semipalmatus ... 191

Charitonetta albeola 190
Chat, Yellow-breasted 200
Chickadee, Carolina 196
Chlidonias nigra surinamensis 192
Chordeiles minor minor 193
Circus hudsonius 190
Clangula hyemalis 190
Coccyzus americanus americanus . 193
erythrophthalmus 193
Colaptes aurates luteus 193
Colinus virginianus virginianus ... 191
Colymbus auritus 188
Compsothlypis americana pusilla .. 199
Coot, American 191
Corthylio calendula calendula 197
Corvus brachyrhynchos brachyrhynchos 195
Cowbird 201
Creeper, Brown 196
Crow, Eastern 195
Cryptoglaux acadica acadica 193
Cuckoo, Black-billed 193
Yellow-billed 193
Cyanocitta cristata cristata 195

Dendroica aestiva aestiva 199
caerulescens caerulescens 199
castanea 199
cerulea 199
coronata 199
fusca 199
magnolia 199
palmarum palmarum 200
pensylvanica 199
striata 199
tigrina 199
virens virens 199
Dolichonyx oryzivorus 201
Dove, Eastern Mourning 192
Dryobates pubescens medianus ... 194
villosus villosus 194
Duck, Common Black 189
Lesser Scaup 189
Ring-necked 189
Ruddy 190
Dumetella carolinensis 196

Empidonax flaviventris 194
minimus 194
trailli trailli 194
virescens 194
Ereunetes pusillus 192
Erismatura jamaicensis rubida 190
Eúphagus carolinus 201

Falco sparverius sparverius 191
Finch, Eastern Purple 202
Flicker, Northern 193
Flycatcher, Acadian 194
Alder 194
Least 194
Northern Crested 194
Olive-sided 195
Yellow-bellied 194
Fulica americana americana 191

Geothlypis trichas brachidactyla .. 200
Glaucionetta clangula americana .. 189
Gnatcatcher, Blue-gray 197
Golden-eye, American 189
Goldfinch, Eastern 202
Goose, Canada 189
Grackle, Bronzed 201
Grebe, Horned 188
Pied-billed 188
Grosbeak, Eastern Evening 201
Rose-breasted 201
Gull, Herring 192
Ring-billed 192

Hawk, Broad-winged 190
Cooper's 190
Eastern Red-tailed 190
Eastern Sparrow 191
Marsh 190
Northern Red-shouldered 190
Sharp-shinned 190
Hedymeles ludovicianus 201
Helmitheros vermivorus 198
Heron, Black-crowned Night 188
Eastern Green 188
Great Blue 188
Hesperiphona vespertina vespertina 201
Hirundo erythrogaster 195
Hummingbird, Ruby-throated 193
Hylocichla fuscescens fuscescens .. 197
guttata faxoni 197

minima aliclae 197
mustelina 197
ustulata swainsoni 197

Icteria virens virens 200
Icterus galbula 201
spurius 201
Iridoprocne bicolor 195

Jay, Blue 195
Junco hyemalis hyemalis 202
Slate-colored 202

Killdeer 191
Kingbird 194
Kingfisher, Eastern Belted 193
Kinglet, Eastern Ruby-crowned 197
Golden-crowned 197

Lanius ludovicianus migrans 198
Lark, Northern Horned 195
Prairie Horned 195
Larus argentatus smithsonianus 192
delawarensis 192
Lophodytes cucullatus 190

Mallard, Common 189
Mareca americana 189
Martin, Purple 195
Meadowlark, Eastern 201
Megaceryle alcyon alcyon 193
Melanerpes erythrocephalus 194
Melospiza georgiana 203
lincolni lincolni 203
melodia beata 202
Merganser, American 190
Hooded 190
Red-breasted 190
Mergus merganser americanus 190
serrator 190
Mimus polyglottos polyglottos 196
Mniotilta varia 198
Mockingbird 196
Molothrus ater ater 201
Myiarchus crinitus boreus 194
Myiochanes virens 194

Nannus hiemalis hiemalis 196
Nettion carolinense 189
Nighthawk, Eastern 193
Nuthatch, Northern White-breasted 196
Red-breasted 196
Nuttallornis mesoleucus 195
Nycticorax nycticorax hoactli 188
Nyroca affinis 189
collaris 189
valisineria 189

Old-squaw 190
Oporornis formosus 200
philadelphia 200
Oriole, Baltimore 201
Orchard 201
Osprey 191
Otocoris alpestris alpestris 195
alpestris practicola 195
Otus asio naevius 193
Oven-bird 200
Owl, Common Saw-whet 193
Eastern Screech 193
Great Horned 193
Northern Barred 193
Oxyechus vociferus vociferus 191

Pandion haliaetus carolinensis 191
Passer domesticus domesticus 200
Passerculus sandwichensis savanna 202
Passerella iliaca iliaca 203
Passerherbulus henslowi henslowi 202
Passerina cyanea 201
Penthestes carolinensis carolinensis 196
Petrochelidon albifrons albifrons 195
Pewee, Eastern Wood 194
Phasianus colchicus torquatus 191
Pheasant, Ring-necked 191
Philohela minor 191
Phoebe, Eastern 194
Pipilo erythrophthalmus erythropthalmus 202
Pipit, American 197
Piranga erythromelas 201
Pisobia melanota 192
minutilla 192
Plover, Semipalmated 191
Upland 191
Podilymbus podiceps podiceps 188

Polioptila caerulea caerulea..... 197
Pooecetes gramineus gramineus... 202
Porzana carolina..... 191
Progne subis subis..... 195
Protonotaria citrea..... 198

Querquedula discors..... 189
Quiscalus quiscula aeneus..... 201

Redstart, American..... 200
Regulus satrapa satrapa..... 197
Richmondena cardinalis cardinalis. 201
Riparia riparia riparia..... 195
Robin, Eastern..... 197

Sandpiper, Eastern Solitary..... 192
Least..... 192
Pectoral..... 192
Semipalmated..... 192
Spotted..... 192
Sapsucker, Yellow-bellied..... 194
Sayornis phoebe..... 194
Seiurus aurocapillus..... 200
motacilla..... 200
noveboracensis notabilis..... 200
Setophaga ruticilla..... 200
Shoveller..... 189
Shrike, Migrant..... 198
Sialia sialis sialis..... 197
Sitta canadensis..... 196
carolinensis..... 196
Snipe, Wilson's..... 191
Sora..... 191
Sparrow, Bachman's..... 202
Eastern Chipping..... 202
Eastern Grasshopper..... 202
Eastern Savannah..... 202
Eastern Tree..... 202
Eastern Vesper..... 202
English..... 200
Field..... 202
Fox..... 203
Lincoln's..... 203
Mississippi Song..... 203
Swamp..... 203
Western Henslow's..... 202
White-crowned..... 203
White-throated..... 203
Spatula clypeata..... 189
Sphyrapicus varius varius..... 194
Spinus tristis tristis..... 202
Spizella arborea arborea..... 202
passerina passerina..... 202
pusilla pusilla..... 202
Starling..... 198
Stelgidopteryx ruficollis serripennis..... 195
Sterna hirundo hirundo..... 192
Strix varia varia..... 193
Sturnella magna magna..... 201
Sturnus vulgaris vulgaris..... 198
Swallow, Bank..... 195
Barn..... 195
Northern Cliff..... 195
Rough-winged..... 195
Tree..... 195
Swift, Chimney..... 193

Tanager, Scarlet..... 201
Teal, Blue-winged..... 189
Green-winged..... 189
Tern, Black..... 192
Common..... 192
Thrasher, Brown..... 197
Thrush, Eastern Hermit..... 197
Gray-cheeked..... 197
Olive-backed..... 197
Wood..... 197
Thryomanes bewicki bewicki..... 196
Thryothorus ludovicianus ludovicianus..... 196
Titmouse, Tufted..... 196
Totanus flavipes..... 192
melanoleucus..... 192
Towhee, Red-eyed..... 202
Toxostoma rufum..... 197
Tringa solitaria solitaria..... 192
Troglodytes aedon aedon..... 196
Turdus migratorius migratorius.. 197
Tyrannus tyrannus..... 194

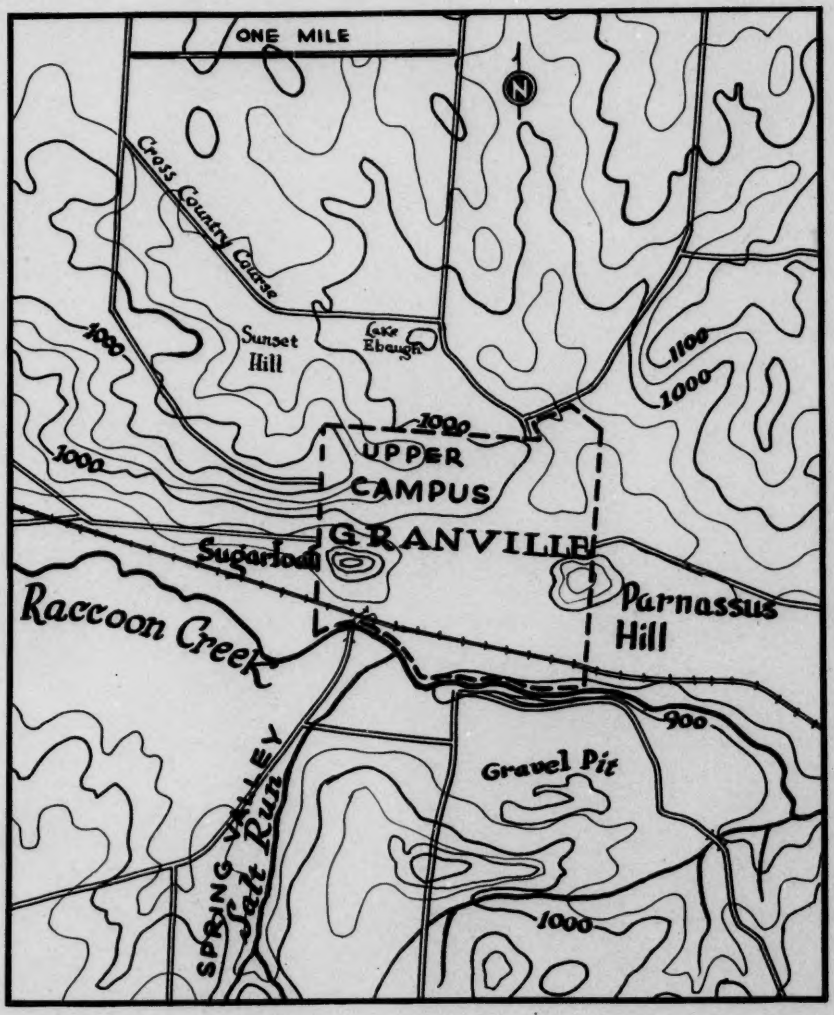
Veery..... 197
Vermivora chrysoptera..... 198
peregrina..... 199
pinus..... 198
ruficapilla ruficapilla..... 199

Vireo, Blue-headed. 198
Eastern Warbling. 198
flavifrons. 198
gilvus gilvus. 198
griseus griseus. 198
olivaceus. 198
Philadelphia. 198
philadelphicus. 198
Red-eyed. 198
solitarius solitarius. 198
White-eyed. 198
Yellow-throated. 198
Vulture, Turkey. 190

Warbler, Bay-breasted. 199
Black and White. 198
Blackburnian. 199
Black-poll. 199
Black-throated Blue. 199
Black-throated Green. 199
Blue-winged. 198
Canada. 200
Cap May. 199
Cerulean. 199
Chestnut-sided. 199
Eastern Yellow. 199
Golden-winged. 198
Hooded. 200
Kentucky. 200
Magnolia. 199
Mourning. 200
Myrtle. 199
Nashville. 199
Northern Parula. 199
Palm. 200
Prothonotary. 198
Tennessee. 199
Wilson's. 200
Worm-eating. 198
Water-thrush, Grinnell's. 200
Louisiana. 200
Waxwing, Cedar. 197
Whip-poor-will, Eastern. 193
Wilsonia canadensis. 200
citrina 200
pusilla pusilla. 200
Woodcock. 191
Woodpecker, Eastern Hairy. 194
Northern Downy. 194
Red-bellied. 193
Red-headed. 194
Wren, Bewick's. 196
Carolina. 196
Eastern Winter. 196
House. 196

Yellow-legs, Greater. 192
Lesser. 192
Yellow-throat, Northern. 200

Zenaidura macroura carolinensis. . 192
Zonotrichia albicollis. 203
leucophrys leucophrys. 203



GRANVILLE AND VICINITY

Some suggested experiments for the graphic recording of speech vibrations; Robert James Kellogg. 14 pp., 6 figs.
The manipulation of the telescopic alidade in geologic mapping; Kirtley F. Mather. 46 pp., 13 figs.
The importance of drainage area in estimating the possibilities of petroleum production from an anticlinal structure; Kirtley F. Mather and Maurice G. Mehl. 4 pp., 2 plates.

Articles 9–12, pp. 147–224; May, 1920 ..... $0.75
Psychological factors in vocational guidance; Thomas A. Lewis. 10 pp.
The use of models in the interpretation of data for determining the structure of bedded rocks; Maurice G. Mehl. 12 pp., 6 figs., 2 plates.
Some suggestions for indicating drilling operations; Maurice G. Mehl. 6 pp., 3 figs.
The Kimmswick and Plattin limestones of Northeastern Missouri; Aug. F. Foerste. 50 pp., 3 plates.

Articles 13–16, pp. 225–329; September, 1921 ..... $0.75
Education for scholarship; William E. Castle. 9 pp.
The cytology of the sea-side earwig, Anisolabis maritima Bon., part 1; Sidney I. Kornhauser. 13 pp., 3 plates.
Notes on Arctic Ordovician and Silurian cephalopods; Aug. F. Foerste. 60 pp., 9 plates.
Revolution vs. evolution: the paleontologist renders his verdict; Kirtley F. Mather. 18 pp.

VOLUME 20

Articles 1–3, pp. 1–36; November, 1922 ..... $0.50
A review of the biology of sex-determination; Sidney I. Kornhauser. 21 pp., 8 figs.
The Meander patterns of Rios Securé and Mamoré, Eastern Bolivia; Kirtley F. Mather. 7 pp., 2 figs.
Primitive musical instruments of the Denison Collection; Karl H. Eschman. 10 pp., 3 plates.

Articles 4–8, pp. 37–186; June, 1923 ..... $0.75
Notes on Medinan, Niagaran, and Chester fossils; Aug. F. Foerste. 84 pp. 13 plates.
The egg and larvae of Hesperia juba Bdv.; A. W. Lindsey. 7 pp., 1 plate.
The occultation of Venus by the Moon on January 13, 1923; P. Biefeld. 4 pp., 1 plate.
A botanical survey of the campus of Denison University; Dwight Munson Moore. 23 pp., 7 figs., 3 plates.
The underground migration of oil and gas; Kirtley F. Mather. 31 pp., 1 fig.

Articles 9–13, pp. 187–383; December, 1924 ..... $1.25
Trichoptilus pygmaeus Wism. and the Neuration of the Family Pterophoridae; A. W. Lindsey. 6 pp., 6 plates.
Notes on American Paleozoic Cephalopods; Aug. F. Foerste. 76 pp., 22 plates.
A Report on the Theory of Relativity (Einstein Theory); Paul Biefeld. 20 pp.
Some Problems of Taxonomy; A. W. Lindsey. 18 pp., 1 plate.
Notes on the Geology of Giles County, Virginia; George D. Hubbard and Carey G. Croneis. 72 pp. 1 plate.

VOLUME 21

Articles 1–3, pp. 1–116; March, 1925 ..... $1.25
Notes on Cephalopod Genera; Chiefly Coiled Silurian Forms; Aug. F. Foerste. 70 pp., 23 plates.
The Cornell University Entomological Expedition to South America of 1919–1920. Scientific Results No. II. Hesperiodea; A. W. Lindsey. 44 pp., 6 plates.
Photographic Record of the Partial Solar Eclipse of January 24, 1925; Paul Biefeld. 2 pp., 1 plate.

Article 4, pp. 117–283; September, 1925 ..... $1.50
The Agricultural Geography of the Salt Lake Oasis; Charles Langdon White. 167 pp., 34 figs.

Articles 5–7, pp. 285–404; September, 1926 ..... $1.25
Actinosiphonate, Trochoceroid and other Cephalopods; Aug. F. Foerste. 100 pp., 22 plates.
Brachiopods from the St. Clair Limestone, Arkansas; Norman L. Thomas. 18 pp., 1 plate.
Notes on the Preparation of Hydrogen Sulfide and Hydrogen Iodide; W. C. Ebaugh. 2 pp.

VOLUME 22

Articles 1–4, pp. 1–135, March, 1927 ..... $1.50
Ordovician and Silurian Cephalopods of the Hudson Bay Area; Aug. F. Foerste and T. E. Savage. 108 pp., 24 plates, 1 map.
Notes on Phylogeny in Erynnis Schr. (Thanaos Auct.); A. W. Lindsey. 7 pp., 1 fig.
The Blue Ridge of Southern Virginia and Western North Carolina; Frank J. Wright. 17 pp., 4 figs., 2 plates.
Gravels of the Blue Ridge; Frank J. Wright. 3 pp., 1 fig.

Articles 5–9, pp. 137–193, October, 1927 ..... $1.00
Science and Religion (Address); Robert A. Millikan. 10 pp.
Forty Years of Scientific Thought Concerning the Origin of Life (Address); Kirtley F. Mather. 11 pp.
Darwin as a Pioneer in Evolution (Address); George A. Dorsey. 14 pp.
Science and Living (Address); C. Judson Herrick. 9 pp.
Founding of the Denison Scientific Association (Address); Alfred D. Cole. 6 pp.

VOLUME 23

Articles 1–2, pp. 1–126, January, 1928 ..... $1.50
American Arctic and Related Cephalopods; Aug. F. Foerste. 110 pp., 29 plates.
Apatodonosaurus, A New Genus of Ichthyosaurs from the Jurassic of Wyoming; M. G. Mehl. 16 pp., 2 figs., 6 plates.

Articles 3–5, pp. 127–230, July, 1928 ..... $1.50
Some Brachiopods from the St. Clair Limestone, Arkansas; Norman L. Thomas. 13 pp., 1 plate.
The Phytosauria of the Wyoming Triassic; M. G. Mehl. 32 pp., 9 figs., 3 plates.
A Restudy of some of the Ordovician and Silurian Cephalopods described by Hall; Aug. F. Foerste. 58 pp., 8 plates.

Articles 6–8, pp. 231–355, December, 1928 ..... $1.50
Hesperioidea from the Kartabo District of British Guiana; A. W. Lindsey. 5 pp., 5 figs.
A Restudy of American Orthoconic Silurian Cephalopods; Aug. F. Foerste. 85 pp., 28 plates.
The Erosional History of the Blue Ridge; Frank J. Wright. 24 pp., 10 plates.

VOLUME 24

Articles 1–5, pp. 1–113, April, 1929 ..... $1.50
Hypoparia and Opisthoparia from the St. Clair Limestone, Arkansas; Norman L. Thomas. 26 pp., 1 plate.
Ordovician and Silurian of American Arctic and Subarctic Regions; Aug. F. Foerste. 54 pp., 2 plates.
Location Factors in the Iron and Steel Industry of Cleveland, Ohio; Charles Langdon White. 16 pp., 4 figs., 1 plate.
A Photographic Record of the Total Eclipse of the Moon; Paul Biefeld. 2 pp., 1 plate.
Basslerina, A New Holliniform Ostracode Genus, with Description of New Pennsylvanian Species from Texas and Oklahoma; Raymond C. Moore. 15 pp., 3 plates.

Articles 6–9, pp. 115–264, August, 1929 ..... $1.50
Some Proparia from the St. Clair Limestone, Arkansas; Norman L. Thomas. 14 pp., 2 plates.
Cephalopods of the Red River Formation of Southern Manitoba; Aug. F. Foerste. 107 pp., 29 plates.
A Large Fish Spine from the Pennsylvanian of North Central Texas; Raymond C. Moore. 7 pp., 1 plate.
Location Factors in the Iron and Steel Industry of the Buffalo District, New York; Charles Langdon White. 20 pp., 6 figs.

Articles 10–13, pp. 265–427, December, 1929 ..... $1.50
Three Studies of Cephalopods; Aug. F. Foerste. 117 pp., 23 plates.
A New Genus of Mosasaurs from Mexico, and Notes on the Pelvic Girdle of Platecarpus; M. G. Mehl. 18 pp., 5 figs., 4 plates.
Stream Piracy near Asheville, N. C.; Frank J. Wright. 6 pp., 1 fig., 1 plate.
Motor Vehicle Transportation Cost and its Relation to Highway Finance; Bruce D. Greenshields. 6 pp., 1 fig.

VOLUME 25

Articles 1–3, pp. 1–164; April, 1930 ..... $1.50
Port Byron and Other Silurian Cephalopods; Aug. F. Foerste. 124 pp., 2 figs., 25 plates.
The Iron and Steel Industry of Youngstown, Ohio; Charles Langdon White. 22 pp., 7 figs.
New Species of Bryozoans from the Pennsylvanian of Texas; Raymond C. Moore. 17 pp., 1 plate.

Articles 4–5, pp. 165–200, August, 1930 ..... $1.00
Visual Localization in the Horizontal Plane; Winford L. Sharp. 9 pp.
Petroleum Products for Internal Combustion Engines; Milton Finley. 26 pp., 3 figs.

Articles 6–7, pp. 201–299, December, 1930 ..... $1.00
The Actinoceroids of East-Central North America; Aug. F. Foerste and Curt Teichert. 96 pp., 33 plates.
The Presence of Nybyoceras in South Manchuria; Riuji Endo. 3 pp., 1 plate.

VOLUME 26

Article 1, pp. 1–142; April, 1931 ..... $1.50
The Hesperioidea of North America; A. W. Lindsey, E. L. Bell and R. C. Williams, Jr. 142 pp., 33 plates.

Article 2, pp. 143-250; December, 1931.....$1.50
The Older Appalachians of the South; Frank J. Wright. 108 pp., 38 plates.

VOLUME 27

Article 1, pp. 1-46; June, 1932.....$1.50
The Geomorphic Development of Central Ohio (Part I); Henry S. Sharp. 46 pp., 1 fig. 6 plates
Article 2, pp. 47-136; December, 1932.....$1.50
Black River and Other Cephalopods from Minnesota, Wisconsin, Michigan, and Ontario (Part I); Aug. F. Foerste. 90 pp., 31 plates.

VOLUME 28

Articles 1-3, pp 1-154; April, 1933.....$1.50
Black River and Other Cephalopods from Minnesota, Wisconsin, Michigan, and Ontario (Part II); Aug. F. Foerste. 146 pp.; for plates *cf.* This Journal, Vol. 27, Art. 2 (December, 1932).
A Study of the Change in Mass of the Anode of the Aluminum-Lead Cell; Charles E. Welling. 5 pp.
Balancing Chemical Equations—The Contribution of Otis Coe Johnson (1830); W. C. Ebaugh. 4 pp., 1 plate.
Article 4, pp. 155-248; October, 1933.....$1.00
The Ordos Desert of Inner Mongolia; George B. Cressey. 94 pp., 32 figs., 1 plate.

VOLUME 29

Article 1, pp. 1-105, April, 1934.....$1.25
The Newer Appalachians of the South (Part I); Frank J. Wright 105 pp., 28 plates, 3 figs.
Article 2, pp. 107-193, August, 1934.....$1.25
Silurian Cyrtoconic Cephalopods from Ohio, Ontario, and Other Areas; Aug. F. Foerste. 86 pp., 14 plates.
Articles 3-4, pp. 195-238, December, 1934.....$1.00
Evidence of Ice Action in the Teays Valley, West Virginia; Julian J. Petty. 10 pp., 4 figs.
The Earlier History of the Bulletin of the Scientific Laboratories of Denison University; Aug. F. Foerste. 23 pp.

VOLUME 30

Articles 1-2, pp. 1-118, April, 1935.....$1.00
Big Horn and Related Cephalopods; Aug. F. Foerste. 96 pp., 22 plates.
New Light Sources for Photographic Purposes; W. E. Forsythe. 22 pp., 7 figs.
Articles 3-4, pp. 119-230, August, 1935.....$1.00
Correlation of Silurian Formations in Southwestern Ohio, Southeastern Indiana, Kentucky and Western Tennessee; Aug. F. Foerste. 87 pp.
A Study of the Phenomenon of Wetting Films; C. W. Chamberlain and Kenneth Lyle Warren. 25 pp., 4 plates, 1 fig.
Articles 5-6, pp. 231-303, December, 1935.....$1.00
The Cephalopods of the Maquoketa Shale of Iowa; Aug. F. Foerste. 27 pp., 11 plates.
New Genera of Ozarkian and Canadian Cephalopods; E. O. Ulrich and Aug. F. Foerste. 32 pp., 1 plate.

VOLUME 31

Articles 1-2, pp. 1-92, April, 1936.....$1.00
Hierosaurus colei; a new aquatic Dinosaur from the Niobrara Cretaceous of Kansas; M. G. Mehl. 20 pp., 3 plates.
Silurian Cephalopods of the Port Daniel Area on Gaspé Peninsula, in Eastern Canada; Aug. F. Foerste. 72 pp., 23 plates.
Article 3, pp. 93-142, August, 1936.....$1.00
The Newer Appalachians of the South (Part II): South of the New River; Frank J. Wright. 50 pp., 6 figs., 32 plates.
Articles 4-6, pp. 143-259, December, 1936.....$1.00
A Study of the Vestigial Air Bladder in the Darter (*Catonotis flabellaris rafinesque*); George David Morgan. 16 pp., 10 plates.
We Must Shape our New World (Commencement Address); Arthur Holly Compton. 11 pp.
Later History of the JOURNAL OF THE SCIENTIFIC LABORATORIES OF DENISON UNIVERSITY; Kirtley F. Mather. 25 pp.
Report of the Permanent Secretary of the DENISON SCIENTIFIC ASSOCIATION. 52 pp.

VOLUME 32

Articles 1-2, pp. 1-131, April 1937.....$1.00
History of *Theta* Chapter of Ohio, Phi Beta Kappa (1911-1936); Willis A. Chamberlin. 69 pp., 2 figs.
The Tungsten Filament Incandescent Lamp; W. E. Forsythe and E. Q. Adams. 72 pp., 10 figs.
Articles 3-7, pp. 133-207, August, 1937.....$1.00
Science and the College (Commemoration Address); Carey Croneis. 12 pp.
Our Endowment (Commemoration Address); C. Judson Herrick. 9 pp.
Science—Man's Liberator (Commemoration Address); William E. Wickenden. 10 pp.
The Application of Physics to Modern Hydrographic Surveying; (Commemoration Address); Herbert Grove Dorsey. 22 pp., 10 plates.
An Annoted Check-list of Birds Recorded at Granville, Licking County, Ohio; Ward M. Klepfer and William J. Taylor. 21 pp., 1 plate.